REPORT

ON

THE TEACHING OF GENERAL SCIENCE

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GENERAL SCIENCE

PREPARED BY THE
GENERAL SCIENCE SUB-COMMITTEE
OF THE
SCIENCE MASTERS' ASSOCIATION

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JOHN MURRAY,
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CONSTITUTION OF THE SUB-COMMITTEE

W. Ashhurst	Epsom College
E H. Coulson	County High School, Braintree
G B. Hindle	King's Norton Grammar School for Boys, Birmingham
H Jennings	Liverpool Collegiate School
E Lucas	Winchester College
D H J Marchant (*Secretary*)	Ilford County High School for Boys
E W. Moore	Thorne Grammar School
W. H Reynolds, M C (*Chairman*)	King's Norton Grammar School for Boys, Birmingham
R Thurlow	Leigh Grammar School
E Yerbury	Liverpool Collegiate School
H P. Young	Whitley Bay Grammar School

1. INTRODUCTION

The Interim and Final Reports of the General Science Sub-Committee appointed in 1935 were published in 1936 and 1938 respectively, under the titles *The Teaching of General Science*, Parts I and II. There is good reason to believe that these reports (particularly Part I) have exercised a considerable influence upon the teaching of Science in the stage of general education in what are now called Grammar Schools. All the Examining Bodies now include General Science as a subject in the School Certificate examination and most of the syllabuses are based directly upon the recommendations in the Reports Mr. Marchant's investigations published in the *School Science Review*, Nos **96** and **107**, show a steady increase in the number of candidates for General Science in the School Certificate and it now compares in popularity with Physics, Chemistry and Biology taken as separate subjects

True to its tradition, the General Committee of the Science Masters' Association felt that this was no time to remain content with a satisfactory state of affairs but that so much experience had been gained in the schools as to the working of the syllabuses that a review of the whole situation seemed very desirable Accordingly a new General Science Sub-Committee was appointed in 1944 and charged with the duty of making this review. This Committee met in October 1944 but decided that the time was not ripe for a full investigation. However, in 1947 the Sub-Committee was reconstituted and the task was begun in earnest.

The present Sub-Committee were agreed that experience has shown that the 1936 and 1938 Reports were sound in principle and that their philosophical background required no serious amendment, but it was felt that the usefulness of the present report to teachers would be increased if these principles were restated. In doing so opportunity has been taken to present them in a form and with an emphasis which recent experience and present conditions render desirable

In considering details of syllabus, and like matters, we have had to take account of several new features in the educational outlook presented by the Butler Act of 1944 and particularly the new system of external examination for Grammar Schools (Ministry of Education Circular 168). It seemed to us that we should bear in mind the needs of three categories of pupil

(i) those who pursue a course of general education from age 11 to 16 and then leave school or discontinue their school study of Science at age 16,
(ii) those who ultimately specialise in Science in the Sixth Form,
(iii) those who ultimately specialise in subjects other than Science in the Sixth Form but who will wish to continue their contact with Science

The basic syllabus that we propose represents the content of scientific knowledge that we consider necessary to an educated citizen and as such is fitted for all pupils in category (i) In this connection we have noticed the increasing tendency for schools to regard five years as the normal duration of the general education course as against the four years assumed in *The Teaching of General Science*, Part I, and we feel that this tendency will be encouraged by the age limitations imposed upon entrants for the new examination for the General Certificate of Education. Thus we have considered it justifiable to increase somewhat the content of our basic syllabus by the inclusion of topics mainly of a chemical nature, the omission of which from the "Minimum Syllabus" of *The Teaching of General Science*, Part I, has been generally felt to have been a weakness. While emphasising that our syllabus is a teaching and not an examination syllabus, we hope that our proposals may form the basis of syllabuses for papers in General Science at the "ordinary" level in the Examination for the General Certificate of Education

Many schools are able to devote more time to Science than the bare minimum we have assumed, particularly towards the end of the course and for those who will ultimately proceed to the Science Sixth Form. We have indicated how we think the additional time available should be spent in treating certain parts of our basic syllabus in greater detail or by the introduction of additional topics. We have been aware of the criticism made from time to time that General Science as set out in the earlier reports is not a suitable preparation for subsequent specialisation in Science We are firmly of the opinion that the arguments in favour of a broadly based course in Science as set out in Chapter 3 apply equally to all pupils, whatever their subsequent history, and we have noted that few, if any, of the schools which have adopted General Science for all pupils find that it is an inadequate background for Sixth Form work. We feel that some of the criticism may have been due to the fact that there was an interval of two years between the publication of the two parts of the Report Thus Part II, which dealt with the additional ground that might be covered by pupils having a larger time allowance for Science than the minimum, has received rather less attention than is its due. By including all our proposals within the covers of the one report we hope to avoid a similar misunderstanding. We note that if the intentions of the Minister and of the Secondary Schools Examination Council are realised, pupils in the second category will not sit an examination in Science subjects until they take the papers at the " advanced " level at the age of 17–18. We hope that the greater freedom in planning courses which should now be possible will result in more of our future specialists in Science following, in the earlier stages of their education, broadly based courses such as that suggested in this report

Pupils in category (iii) will presumably cover the ground of our syllabus during the general education phase and will subsequently devote not less than two periods per week to Science in the Sixth Form We feel that they should follow a course which takes account of their more mature outlook and our suggestions follow very closely the recommendations of the Sub-Committee of the Science Masters' Association on the teaching of Science to non-science specialists, whose Report is published in the *School Science Review*, No 99 (February 1945) We hope that examining bodies will set alternative papers in General Science at the ordinary level on these lines.

In articles and letters in the *School Science Review* we have noted the existence of an unfortunate impression that the earlier Reports encouraged the use of demonstration experiments at the expense of individual work done by the pupils themselves. We have been at pains to correct this impression by including a chapter dealing with Practical Work in general and by adding to our syllabus a schedule for practical work, both individual and demonstration, which we hope will not only make our intentions in this matter perfectly clear but be of assistance to young teachers in the planning of their work

In setting out the details of the syllabus we have thought it well to abandon the " broadsheet " method adopted in the earlier Reports (*The Teaching of General Science*, Parts I and II), and to use three columns, one for the actual syllabus, one for observations upon it, and the third for suggestions for practical work.

Conditions both of laboratory accommodation and staffing vary greatly from school to school The ideal of laboratories which can be reserved and equipped for General Science, and a science staff composed of members all of whom have received a broadly based science training is seldom attained and we have thought it useful to include in the chapter on " Special Considerations " suggestions based on experience as to how typical difficulties of this kind may be met.

We have given careful consideration to the problem of Science teaching in Secondary Modern Schools and as to how far our suggestions might be of use in this connection We have come to the conclusion that such problems deserve separate consideration and have decided to omit specific reference to them in our Report, being confirmed in our attitude by the knowledge that the General Committee of the Association is setting up a Sub-Committee to deal with them. It is, however, our hope that this Report, particularly the parts dealing with the work of the early years of the course, may be found to be of considerable use to teachers in Secondary Modern Schools in planning the details of their work.

The chapter on " Examinations " in *The Teaching of General Science*, Part II, appears to have had some influence on the types of paper set in School Certificate Examinations of the various Examining Bodies. We feel, however, that the suggestions for the types of question have received less consideration than they deserve ; we are therefore reprinting with suitable modifications the part of the chapter which deals with this topic.

We have had the advantage of hearing the views of His Majesty's Inspectors on certain aspects of our Report through a deputation from the Sub-Committee which met the Science Panel of the Inspectorate, by invitation, on April 13th, 1949.

2. THE HISTORY OF THE GENERAL SCIENCE MOVEMENT

THE growth of the General Science movement within the Science Masters' Association may be traced back as far as 1915 when the Committee of the Association of Public School Science Masters, the parent body of the S M A, appointed a Sub-Committee to report on ways and means of furthering the claims of Science as a school subject

A brief summary of its subsequent development is as follows :

1916 The Committee of the A P.S.S M. drew up the memoranda *The Aims of Science Teaching in General Education* and *Science for All*

Jan. 1919 General Science was discussed at the Annual Meeting of the S.M A.

Dec. 1920 An article, " Science for All , a Plea for General Science ", was published in the *School Science Review.*

1924 The S.M A Committee prepared a new pamphlet on " General Science " and successfully pressed for the inclusion of General Science as a subject in the School Certificate Examination.

1932 The General Science (1924) pamphlet was revised.

1933 A Sub-Committee was appointed to consider the aims, content and method of a course in Elementary Science such as was suggested by the Panel of Investigators which had enquired into School Certificate examinations. Their report was discussed at the Annual General Meeting in 1934

1935 A new Sub-Committee under the Chairmanship of Mr. C. L. Bryant was appointed to go further into the question of General Science. Their Report which is in two parts was adopted by the General Committee and published by John Murray under the title . *The Teaching of General Science*, Part I appearing in 1936 and Part II in 1938.

1944 A new General Science Sub-Committee was appointed to review *The Teaching of General Science* in the light of experience gained of its working This Committee came to the conclusion that the time was not ripe for discussion of changes.

1947 The present Sub-Committee was appointed and commenced its work

Those who are interested will find a fuller treatment of the earlier work in *The Teaching of General Science*, Part I, Chapter 3.

3 THE AIMS OF SCIENCE TEACHING

(This chapter, which is felt to be a necessary concomitant of any Report on the Teaching of General Science, is a reprint of Chapter 4 of *T G S.*, Part I, with some modifications)

BEFORE entering on any discussion of the contents of courses or of the method of teaching Science in the early stages, it is desirable to state the aims which teachers of the subject have in mind.

Analysis of views generally held shows that the numerous reasons urged to justify the inclusion of any subject in the curriculum can be roughly classified under three headings.

(*a*) utilitarian or vocational it helps the pupils in their everyday life, or may be necessary in their future occupations ;

(*b*) disciplinarian it teaches them to think, it sharpens their minds ;

(*c*) cultural : its inclusion is desirable because it forms an essential part of our social heritage

The study of Science is certainly useful, both for the community and for the individual. As to the former, the prosperity of a nation, indeed its very existence, requires a continuous supply of highly qualified technical experts. But the preparation of such experts cannot be considered as one of the functions of the school, for technical training can be carried on efficiently only in specially equipped institutions ; and it need not be started before the age of sixteen years Moreover, the total number of technicians actually engaged in fundamental research, or in work requiring specialised scientific knowledge, forms only a very small proportion of the total population In a Secondary School a course which acquires meaning only when completed by advanced studies cannot be wholly satisfactory and should not be attempted

The initial training of experts is, however, one of our tasks, and this can best be achieved by a broad syllabus ; for it is at school that particular talents are discovered and their development fostered Many a potential specialist, in the life sciences especially, has been lost to the world by the narrowness of the teaching at school. Moreover, much of the work of the expert is concerned with advising specialists in other fields, and his task will be facilitated if he has some appreciation of their interests and activities, and some knowledge of the special terms they employ.

In one way especially the teaching of Science to all benefits the community. A state will best function when the intellectual climate in which its members live is suited to the tasks they perform. Scientists and inventors do better work when their efforts do not meet blind opposition, and when the spirit of the times is in sympathy with them. Further, it is desirable in the highest degree that the members of a democracy should understand, even if only in simplified form, the general inter-relationship of the trades and occupations of their country and that they should appreciate the utility of the expert and the kind of advice he may be trusted to give. We should therefore give our pupils some notion of the many ways in which Science enters our lives and has influenced and altered our occupations. We should show them that its study requires a particular mode of approach to problems, that the scientific spirit implies the dispassionate analysis of well-authenticated data, and that prejudice, superstition and dogmatic assertion are the enemies of vigorous development. Clearly, these objects are not to be achieved by the intensive study of too restricted a field. We must choose our samples so as to illustrate a large range of science and its manifold ramifications Though the aim discussed above is too wide and possibly too vague to give immediate practical guidance it does reinforce the generally accepted idea that the school science course must find its starting-point and its inspiration in the actual human environment

To the individual, the study of Science may be useful, in the narrow sense of the word, in two ways (*a*) it may help him to earn his living, and (*b*) it may help him to carry out more efficiently the activities of his ordinary life

The exclusive acceptance of the first of these two claims would lead us to arrange vocational courses While these have the advantage of stimulating the interest of our pupils, they suffer from two great drawbacks. Firstly, a purely vocational curriculum presupposes a static, unchanging society. It is built up by studying the activities and trades in which people are actually engaged at the moment and then dealing with these But, in fact, these occupations change and we cannot know precisely what scientific knowledge will be found vocationally useful in twenty-five years' time. Secondly, the occupations of the people exhibit such amazing diversity that it is impossible to cater specifically for more than a small fraction. Hence we cannot consider vocational preparation as one of our main aims in a Secondary School.

In ordinary life, however, opportunities for using scientific knowledge are rapidly increasing in number While it is true that no item of scientific knowledge can be considered essential, few will deny that even the most rudimentary acquaintance with scientific facts and principles can often be directly useful. Some knowledge of Biology, for example, can help towards more rational and healthy living This subject forms the best foundation for a study of the laws of hygiene, and an appreciation of the data underlying practical hygienic advice may facilitate its rapid adoption. But here again, while admitting the possible value of such claims, it is not easy to see how they will help us to decide what to include in, or what to exclude from, the curriculum. The total number of contacts is so vast as to be almost coextensive with the whole range of modern science

Perhaps the most important reflections which arise from these considerations are ·

(*a*) the importance of a broadly conceived course touching ordinary life at many points , and

(*b*) the great importance of stressing scientific principles of wide generality, for when these are thoroughly understood, their useful application may easily be extended

The second claim advanced in favour of the teaching of Science has been based largely on a belief in the possibility of a transfer of training. The study of Science is said to develop certain powers of clear and vigorous thinking, of coherent and logical deduction, of exact and accurate observation. All these are very desirable qualities and their more general diffusion must be assisted in every way. Many teachers of Science hope that habits of this sort, acquired in the classroom, will automatically be generalised and applied to the wider concerns of national life. Such arguments were often urged in defence of the courses in weighing and in practical measurements which have served to introduce the study of Science to so many young children.

This is not the place to discuss at length this vexed question. We would point out, however, that *experimental* evidence has shown quite definitely that the possibilities of transfer of training are much smaller than had formerly been supposed [1] On the other hand, it has been shown that the importance of the *sentiments* which grow up around any subject cannot be overestimated. It is essential for future success that a child's first introduction to Science should not lead to boredom, to a feeling of failure or insufficiency, or to an impression that it is a formalised study not directly applicable to things that interest him

The influence of these results on our work is obvious. Since the "disciplinary" values of a subject cannot be urged as the main arguments in its favour, we must not include in our syllabuses any matter whatever which is taught only for the sake of the training it gives. It is no longer possible to defend a narrow curriculum by urging the claim that it "trains boys to think and to appreciate scientific method". It is doubtless true that a concentrated course in Chemistry, for instance, may teach a boy to use chemical concepts efficiently, but it is not worth great expenditure to train as budding chemists boys who will not become chemists. They will not necessarily become better scientists, still less better citizens.

It must be the conscious aim of the teacher to inculcate in his pupils and to transfer to their general outlook such aspects of the scientific discipline as—

(*a*) accurate observation, separating the relevant from the irrelevant in a purely objective manner uninfluenced by prejudice or bias ,

(*b*) a willingness to conduct careful and thorough experiments taking account of possible errors even of trained observers, remembering the limits of accuracy of any observer and distrusting mere authority ;

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[1] We are indebted to Sir Cyril Burt for a concise statement on the current views on the question of transfer of training

(c) the intelligent estimation of the reliability of the results obtained ;

(d) the classification, evaluation and logical interpretation of the data so obtained ,

(e) the formulation by clear reasoning of a hypothesis from a sufficient number of such results ;

(f) the testing of this hypothesis by further results until it is confirmed and accepted as a natural law or rejected or extended by additional hypotheses, thus paving the road to further advances in our knowledge.

In connection with the third claim advanced in favour of the teaching of Science—the cultural value of the subject—it should be remembered that the school is, above all, a place where children undergo carefully selected experiences which we believe will be of value to them, both immediately and in adult life. Since they will become full members of a community which has enshrined its beliefs and ideas in particular modes of thought and of expression, we believe that all children have a right to demand of us the opportunity of appreciating the meaning of these We recognise fully the fact that the genius of the Western peoples has found very rich and satisfying expression in a literature and an art of high excellence, but we would urge that their peculiar intellectual glory has been the creation of a Natural Science which is far in advance of that of earlier times

No one can be considered truly cultured who has never had his imagination stirred by this great adventure—the scientific exploration of natural phenomena. Of all the claims made for the inclusion of Science in a school curriculum, one of the strongest undoubtedly is that which stresses the cultural value which the subject possesses.

The foregoing considerations lead us to the conclusion that we should arrange our courses in as liberal a manner as possible, and that they should be designed to cover a wide range, at any rate in the initial stages.

Turning now for a moment from the subject-matter to the pupils that we teach, we should realise that Natural Science is unique in the appeal it may make to their spirit of inquiry. Any method of teaching which destroys that curiosity is foredoomed to failure. Children are so inquisitive about themselves and their environment that it is folly not to take advantage of the opportunity which they themselves offer us to teach them the things they are eager to know. Stated thus briefly, the matter seems simple, but it must be remembered that the interests of children change rapidly between the ages of eleven and sixteen years. Suffice it now to say that, in framing our syllabus, the natural curiosity of the pupils influenced us at least as strongly as the logical sequence of ideas with which we as adults have become familiar

General Science should therefore be a course of scientific study and investigation which has its roots in the common experience of children and does not exclude any of the fundamental sciences. It seeks to elucidate the general principles observable in nature, without emphasising the traditional division into specialised subjects until such time as this is warranted by the increasing complexity of the field of investigation, by the developing unity of the separate parts of that field and by the intellectual progress of the pupils

4. CONSTRUCTION OF THE BASIC SYLLABUS

THE criteria which were postulated as governing the selection of subject-matter in the "Minimum Syllabus" (see *Teaching of General Science*, Part I, Chapter 5) were—

(1) The subject-matter chosen must be such as to 'call forth activity on the part of the pupils' (p 17). Hence it must interest them as much as possible

(2) 'Every item in our syllabus should lead to the understanding of fundamental scientific principles' (p. 18)

(3) The syllabus must provide 'a field suited to the cultivation of those habits, interests and sentiments which are fundamental to Science' (p. 18)

Following the procedure which was adopted for the selection of material in *T G S*, Part I, the Committee divided into three panels, one for each of the Chemistry, Biology and Physics sections Each panel consisted of three members, one of these drew up a list of 'contacts' for his part of the subject, i e topics in which pupils would be interested and with which they might well expect to become familiar; another member set down the principles which were considered fundamental to an understanding of the subject at the stage being considered; and a third member had the task of correlating the material provided by the other two This procedure led to the first draft of each section The material was then arranged under appropriate headings with a suggested allotment of periods for each, and notes were added to indicate the kind of treatment suggested.

A consideration of the time allotment for the course was naturally involved in this selection of subject-matter. The original Report set forth a syllabus for "the barest minimum of Science with which all boys who pass through our Secondary Schools should be acquainted" (p 21) and the time basis agreed upon was 16 year-periods. But this adoption of the "barest minimum" has provided a lever for those who impute superficiality to General Science and a supposed excuse for the reduction of time allowance for Science courses in some schools This is a general tendency which will, no doubt, be accentuated by the changed regulations for the General Certificate of Education It was decided, therefore, to plan for a basic course of 20 year-periods of 45 minutes each, as being the *minimum* time for the subject to receive adequate attention with any reasonable hope of securing the third criteria mentioned above, viz the " cultivation of those habits, interests and sentiments which are fundamental to Science ", whilst at the same time realising that many schools will have a more liberal time allotment.

The drafts of all the sections were next subjected to a careful scrutiny by the whole Committee ; in the course of this procedure, many valuable discussions were embarked on, leading to much rearrangement of topics and the introduction of many amendments It is interesting to notice that each member of the Committee acted in two different ways during the construction of the Syllabus as a specialist in at least one branch of Science when contributing to the collection of material and as a General Scientist during the critical stage of examination. It is hoped that the final Syllabus will therefore be acceptable, not only as a coherent plan of work in General Science, but also as a suitable background for more advanced studies in any of the separate Science subjects.

The number of periods to be devoted to each part of the Syllabus is shown in brackets. It is quite likely that different teachers will spend more or less time on any portion—indeed, it is most desirable that there should be this variety of treatment ; the estimate of periods for each portion is intended merely as an index to the depth of treatment which the Committee had in mind when making these proposals and the whole scheme is put forward as one possible way of dealing with this subject-matter The phraseology used is not the calculating, legal idiom of the examination syllabus, nor is it suggested that all the topics referred to in the syllabus are suitable subjects for examination

For reasons stated in the Introduction and in the chapter on Practical Work, it has been thought advisable to put forward a scheme of Practical Work to accompany each section of the Syllabus now presented. Various members were asked to draw up their own schemes first and then to compare later ;

a remarkable feature of this procedure has been the close correspondence between these lists which were, of course, drawn up independently. In those few cases where one member, advocating individual experiments for a given topic, differed from another member advocating demonstration, there was rarely serious difference of opinion and either treatment might well have been adopted These lists of experiments will, it is hoped, prove beyond doubt that there is no ground for the above-mentioned criticism (see p. 3) and prove a useful guide to less experienced teachers. But they should be regarded only as possible ways of treating the subject, i.e. as suggestions rather than as recommendations

It is instructive to compare the " Minimum Syllabus " with this revised Syllabus, as set out in Chapter 6. A detailed comparison is left to the reader, but one or two points deserve comment The content of the Biology Section was the subject of much interesting discussion In a Chemistry course it is difficult to avoid a more or less conventional and logical sequence of subject-matter and the same is true of each subdivision of Physics , but there are different possible sequences for the development of a Biology course The present scheme, which is considered to be a more successful synthesis than the earlier one, represents an attempt to combine the advantages of both the " natural history " and the " physiological " modes of approach In framing the Biology Section it was agreed, after careful examination of existing syllabuses, that the following principles be used as the basis . (1) the essential interdependence of animals and plants, (2) the matter-energy relation, by which is meant the chemical and physical phenomena which are essential to life, and (3) the necessity for all living organisms to adapt themselves to their environment

It is recognised that these principles are not unconnected and they should therefore not be taught separately, but they should be always present in the background of the teacher's mind throughout the course, and it is hoped they will be perceived by the pupils at the end The cell as a unit of life can be used further as a unifying factor. It will be noticed that in the first year the natural interest which children have in familiar animals and plants is utilised and the matter-energy principle is gradually introduced in the second and third years when the chemistry and physics portions of the syllabus give the best support, and the adaptation principle is exemplified in the fourth and fifth years.

The interdependence principle, whilst studied in some of the lessons of course, can best be imparted by a study of some particular habitat during field excursions and by the study of creatures in vivaria, aquaria, school gardens, and the like. (Town schools may only be able to do the latter) The course throughout aims at extending the pupil's range of contacts with his organic environment, thus helping him to understand more fully such questions as food and water supply, problems concerned with medicine and hygiene, some simple facts about heredity. At the same time, it is hoped that this course will produce a widening of interests resulting from an informed knowledge of the countryside

The present Chemistry section seeks to meet criticism which has been voiced that Chemistry was neglected in the " Minimum Syllabus " by the inclusion of rather more material, with the result that a more equitable distribution of time between the branches is obtained. Moreover, one of the much-heard objections to General Science that we have tried to meet is that it does not form an adequate grounding for Sixth Form work, and by introducing more Chemistry we have tried to remedy what some have felt to be a defect.

The changes in the Physics Section are not so easily traced at first sight since they are, for the most part, concerned with minor amendments and transpositions Work on electrolysis and cells, for example, has been removed to the Chemistry Section. Some portions, as for instance work on friction, surface tension and vector quantities are not included ; it is argued that these belong, more correctly, to the Extended Syllabus One likely outcome of these changes is that a more thorough treatment of the Physics will be possible in the available time.

5 PRACTICAL WORK

SCIENCE is largely experimental and the teaching of Science should be based on experiment or observation. In the early stages, in particular, there should be in every lesson some specimen to be observed or some apparatus, however simple, to be manipulated. A good Science lesson is an inquiry, an investigation. The class should be led from the familiar, everyday phenomenon, or from some familiar everyday application of Science, to inquire further into its nature ; and if this inquiry is to be conducted scientifically it will be necessary to make direct observations or the controlled observations we call experiments. So strongly do we feel this to be so that we have prepared a schedule of suggestions for suitable practical work for every section of the syllabus

It should not be thought that we are proposing that everything that is learnt in a Science lesson should be elicited from experiment ; school life is too short for that ; nor should experiments be given to a class just to give them something to do ; each class experiment should justify the time and expense it necessitates. Much information will be imparted didactically or derived from reading, but this should be regarded as information acquired from more or less reliable authority, not as knowledge acquired by scientific technique, and, we emphasise, rarely should a lesson be devoted wholly to study of that kind

Nor must it be supposed that we are suggesting that every investigation should be conducted entirely by the pupils Even if that were possible it would still be undesirable to deprive them of the valuable lessons they can learn by watching the skilled manipulation of the teacher So while we do assert that wherever possible the investigation should be performed by the pupils themselves, either at their benches or in the field, nevertheless occasions do arise when the manipulation must be wholly or partly in the hands of the teacher and what has been called a demonstration lesson is desirable. This will happen when the experiment would be too dangerous in unskilled hands, or when the necessary equipment is too expensive, or when it is necessary to complete a piece of work more quickly

This so-called demonstration may still be an investigation and need differ from the class experiment only in that one set of equipment is used instead of many and that the manipulation is partly, or sometimes wholly, in the hands of the teacher. For this kind of lesson the term demonstration is not really appropriate. It is, of course, possible to demonstrate, but we do not think that, in general, it is the best technique. ‘To show that, when hydrogen burns in air, water is formed’ is to demonstrate ; ‘To investigate the product of the burning of hydrogen in air’ is an experiment which is safer in the hands of the teacher. The experiment should be directed by the class and individual pupils may take part, for example, in testing the liquid product. The difference lies in the mental attitude and a lesson of this kind may be as stimulating to the class as individual practical work. Indeed, it may well be true that certain types of pupil, whose abilities are not manual, derive greater satisfaction and acquire a clearer knowledge from this vicarious experimentation

Demonstration in the true sense has, of course, its limited place in the Science course when we wish to teach some necessary skill, e.g the use of the chemical balance, or when the operation is too difficult for the immature pupil, e g. the dissection of an animal.

It has been thought by some that by reason of the breadth of the General Science syllabuses it is necessary, in order to cover the ground, for experiment to be replaced by “talk and chalk”, or at least for the teacher to perform most of the practical work, so that the class is taken on a sort of char-à-banc tour of Science. This idea we most strongly resist. The normal child soon loses interest in a conducted tour, but he is avid in his desire to explore for himself; and by careful planning of the practical work, by excluding much of the formal and repetitive work which has often characterised the teaching of Physics and Chemistry, and by a wide employment of the simple and often beautiful methods which science masters have devised (many of which have been described in the *School Science Review* and the “Science Masters’ Books of Experiments”), we believe that this can be achieved. It should always be remembered that we are aiming at giving the pupil a broad general education, and not, at this stage, making him into a skilled technician. Thus, for example, we should be satisfied if he has shown that there is a constant relationship between the quantity of oxygen and hydrogen that enter into reactions with a given mass of metal without requiring him to attempt a series of determinations of equivalents of doubtful accuracy and subsequently to solve numerous arithmetical problems to illustrate them.

This should not be interpreted as meaning that in teaching General Science we can be content with slovenly and inaccurate knowledge ; on the contrary, it must be insisted that Science is an exact study, and that measurement is fundamental. A glance through the syllabus will show how many of the experiments we suggest involve some quantitative work. But we resist the idea that measurement for its own sake is of high value in a general education

Measurements should be made, and the skills of weighing and measuring taught, when the need for them has been realised , and the degree of accuracy demanded should be related both to the problem and to the stage of development of the pupil. Thus, for example, to give in the early stages of a Science course a full description of the chemical balance and then to make determinations of, say, densities as exercises in the use of the balance, we believe to be a fundamentally wrong approach and one wasteful of time.

If we recall the history of almost any scientific development we see a completely opposite approach. In the determination of the Gravitational Constant, Maskelyne used a mountain for his mass , later Cavendish used a torsion balance with a six-foot beam and masses of lead one foot in diameter , still later, Boys employed a greatly refined torsion balance with a nine-inch beam So in our teaching in the early stages we recommend the use of large masses and direct-reading balances, e.g. household scales In this way rapid determinations are possible and the issue is not confused by difficulty of manipulation or computation. Later, when the need for greater precision has been felt, or when the masses to be handled are necessarily small, the refinements of the chemical balance should be given. By this time the pupil is more mature, mastery can be achieved in a much shorter time and the work acquires that faster tempo which should characterise the teaching of General Science

The same, of course, may be said of all measurements · thus an early measurement of length will be the height to which water rises in a bell-jar after burning phosphorus, while, later, expansion of solids may involve the use of the micrometer or vernier

Whilst individual practical work of a quantitative nature in Physics gains much in clarity by an increase in scale, much of the necessarily qualitative work in Chemistry can, with advantage, be performed by pupils using small quantities of materials. Such small-scale work, besides leading to a considerable saving of time and reagents, enables pupils to do for themselves many experiments which, on account of either expense or possible danger, would otherwise have to be demonstrated by the teacher. For example, many reactions may be carried out with drops of solution on a cavity tile or glass plate, gases may be collected and their properties studied in test-tubes or specimen tubes instead of gas-jars. For reference to recent work in this field, which provides many opportunities for research by teachers, attention is directed to the bibliography

(A perusal of the instructions given for practical work in many text-books shows that it is still necessary to add two cautions. The first concerns the tendency to make generalisations from one instance ; for example, from an experiment on the expansion of iron, it is not possible to infer that " solids expand on heating ". It is true that it is neither possible nor desirable for each pupil to repeat his investigation with a large number of instances, but where the experiment is conducted by the class, individuals can frequently be given different examples and a generalisation can be inferred from the class results When this is not possible, the conclusion from the experiment is specific and, while a generalisation will frequently be supplied by the teacher, it is a grave disservice to Science to allow the pupil to suppose that his experiment has established it. The second concerns telling the pupil in advance the results he should expect from his experiment. To do so is to rob him of any chance of experimenting at all, His interest is then centred on getting the " right result " and he is no longer able to investigate. It is always necessary to give him precise instructions about procedure, but he should be taught to pride himself on the integrity of his own observations.

We have dwelt on this question of practical work because there appears to have been widespread misunderstanding of the intentions in this matter of the authors of the previous Report The aim has always been to secure in the General Science course a breadth of treatment, not by the reduction of practical work, nor by the replacement of individual practical work by demonstration, but at the expense of many of the academic exercises which have become traditional in the teaching of the specialised branches of Science. If in the past some of the work that has been called General Science has been inadequate, whether for the average pupil for whom it represents the whole of his scientific studies, or for the fewer for whom it has to be the foundation for further more specialised scientific training, all we can say is that any subject can be badly taught, and while any part of Science can be so taught as to be a valuable discipline, surely it is better that this discipline should be acquired against as broad a background as possible than that it should be narrowly confined to one type of investigation.

(For an excellent discussion of aims of practical work, see *Science and Education*, S. R Humby and E J F James (Cambridge))

6. THE BASIC SYLLABUS

PRESENTATION

Having arrived at the content of a syllabus it was necessary to choose a form in which to present it. Following the example of our predecessors we decided "to maintain the customary classification into the three main branches of Science though not implying that this division need be maintained when teaching" (*T.G.S.*, Pt. I, p. 22).

Some may still feel that this is wrong in principle and that General Science should be presented as a unified whole. It is true that the environment of the child is undifferentiated and that it is wise as an approach to choose some "topic" which captures interest and provides a bridge between the various parts, yet we feel that such approaches belong rather to methods of teaching than means of presenting the syllabus, which after all is the mere skeleton to which the teacher must add the flesh and blood.

It is also certainly true that "whatever scheme teachers may adopt it will be found in practice that they soon group like with like so as to exhibit logical connections, thereby reaching a division of their field of study not so very different from that usually adopted" (*T.G.S*, Pt. I, p. 23) Indeed, we would add that the history of science itself shows that it is upon such successful groupings that progress has largely depended. The "topic" method of approach has its greatest value in the early years of the course and here we would make it clear that we envisage that at least for the first two or three years of the course it will become increasingly common that all the science teaching of a particular form will be in the hands of a teacher working in an "undifferentiated" laboratory Under these circumstances he may range from one section to another according to his own method of approach. We conclude this chapter with some examples of "topics" that have been found successful in practice. We would, however, add a warning that if the use of such "topics" is pushed too far the method may easily raise more difficulties for the pupil than it removes. We have decided to abandon the broadsheet method employed in the previous reports, firstly because it has proved to be somewhat inconvenient in practice, and secondly because we wished to add matter on practical work, etc , which would have made the sheets too clumsy. This has the disadvantage, however, that it is not so easy to follow the relation between the subject-matter in the three sections. When considering the order in which the subject-matter should be presented it was found that correlation was most satisfactorily achieved on the basis of the Biology syllabus The content of the Chemistry section was where necessary arranged to support the Biology. The relation between the Physics and the other two sections was found to be less close than that between the Biology and Chemistry ; accordingly, after securing that such Physical topics as are required in the other sections were introduced in appropriate places the main criterion in deciding the order in this section was the stage of development of the pupils

There is divergence of opinion among teachers as to the ideal method of approach in the Biology Section of the work. For example, some would advocate the approach by way of Field Studies, while others who regard the pupil's own body as his most immediate environment would make human physiology the first consideration. The order set out in this Report was arrived at after considerable discussion by the whole Committee. Even so, it was felt desirable to indicate alternatives, particularly in the work of the first year. We do not expect that our scheme will receive universal acceptance, nor do we wish this. Indeed, we would emphasise strongly that our proposals as a whole represent but one possibility among many of arranging the work, and we hope that they will be used by way of guidance by schools in framing their own schemes in the light of their special circumstances and requirements, rather than as prescriptions to be followed in detail Although our syllabus has been set out on the basis of a five-year course, we realise that there are likely to be considerable variations in the organisation of different schools and of different 'sides' in the same school. It appears that these variations are much more probable in the fourth or fifth years than in the first three. With this situation in mind the material of the first three years of the course has been designed to have a unity of its own and to be a foundation upon which a variety of superstructures can be raised. We hope, however, that the subject-matter of the entire basic syllabus will be introduced at convenient stages during the school life of every Grammar School pupil, since in our view it represents the minimum scientific equipment for the intelligent appreciation of his environment.

THE BASIC SYLLABUS

Under the heading "Practical Work" in the details of the syllabus, matter in italics is probably more suitable for demonstration than for individual work by the pupils.

S.S R = School Science Review

YEAR I

A BIOLOGY

The main aims of this portion of the work are (*a*) to develop interest and (*b*) to build up a fund of experience by means of observations upon the major activities of plants and animals, such as respiration, nutrition, reaction to stimuli, growth and reproduction

Such characteristics of living organisms may readily be studied in such familiar organisms as the broad bean plant, the frog and the butterfly, or house-fly or blow-fly There are very many possible ways of teaching this first-year biology, and the arrangement of the work can be varied according to the particular ideas and interests of the teacher Schemes I and II are suggested as possible alternatives, and the suggestions given at the end of the first-year syllabus provide other alternatives

SCHEME I

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
	A INTRODUCTORY STUDY OF FLOWERING PLANT		
(1)	(i) Study of common plant as consisting of root, stem, leaf and flower	Direct attention to parts of the plant and train in making and recording observations	Drawing and examination of plant, e g deadnettle Collect and examine others
(2)	(ii) The seed, e g bean	Training in use of hand lens, needles, etc , important	Dissect and draw. Collect and examine other seeds
(4)	(iii) Germination of seed Conditions for germination	' Collection ' of seeds, etc , used to extend ideas from ' type ' to	Plant in boiling-tube, also one other suitable type brought in by pupil Experiments to show necessity of

		give idea of variety.	warmth, water. Air necessary and soil not necessary. Control experiment
(2)	(iv) The seedling. Responses to light and gravity.	Cress useful for root hairs.	Grow and collect seedlings Simple phototropism and geotropism experiments *Control with klinostat*
(2)	(v) CO_2 produced in germination. Heat given out Compare with burning Carbon present in plant tissues	Emphasise importance of control experiments.	Seeds germinated in flask with lime-water Control with poisoned seeds *Thermos experiment with control* Char plant tissues.
(2)	(vi) The leaf Section of leaf. Demonstration of cells Elementary idea of plant nutrition Oxygen from leaves		*T S of leaf under microscope or microprojector. Elodea experiment with lantern.*
(1)	(vii) Animal nutrition Dependence on plant life.	The aquarium study as an example of a simplified plant and animal community	Observations on balanced aquarium tanks, especially such changes as the effect of water snails in reducing algal films and Daphnia in reducing suspensions provided they are not eaten by sticklebacks.
	B. THE FROG		
(10)	(i) Its life history from the egg as a study of growth and development	Pick out one organism for more detailed study	Collect and keep in small aquaria and some in large aquaria with carnivores and other pond animals, e g. Hydra and examine week by week
	(ii) The tadpole Respiration with gills and blood circulation in gills.		Observe under microscope. Put tadpoles in boiled water to illustrate need for oxygen.

YEAR I—BIOLOGY (*continued*)

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
	(iii) Reactivity in frogs		Studies for conditions for pallor and darkening of skin—background, moisture and warmth
	(iv) The mating of frogs. Fusion of cells.		
(8)	C. INSECT STUDIES.		
	(i) Structure and life history of common butterfly or house-fly or blow-fly	Encourage pupils to bring in and rear other species.	Obtain (collect if possible) eggs of one species and rear in lamp chimneys
	(ii) The Honey Bee. Social life.		*Observation hive if possible Examination at various times of the year*
	(iii) Reactivity.	Drosophila easier and pleasanter than blow-flies in experiments suggested.	Fairly rapid colour change in white butterfly pupae in coloured boxes. Responses to stimuli—caterpillars (contact), adult flies (light and smell)
(4)	D. FLOWER STUDIES.		
	Structure of flower Formation of seed Pollination and fertilisation.	Observe actual pollination occurring and thus avoid assumption that hive bee is the only insect concerned.	One species examined and drawn in laboratory Others collected and named by pupils Pollinating agents observed Germination of pollen grains in sugar solution

Total 36

SCHEME II

INTRODUCTORY STUDY OF THE FLOWERING PLANT, FROG, INSECTS

(1)	1. Study of a common plant, as consisting of root, stem, leaf and flower.		Draw and examine plant such as deadnettle. Collect and describe other species.
(2)	2 The Leaf Section of leaf and demonstration of cells Elementary idea of plant nutrition		*T S leaf (microscope or micro-projector) Elodea experiment with lantern to show evolution of CO_2*
(1)	3 Animal nutrition and its dependence on plant life.		Observations on balanced aquarium tanks Water snails reducing algal film Daphnia reducing suspensions unless eaten by sticklebacks or Hydra
(3)	4. Insect studies. Structure and life-history of a common butterfly or moth, or house-fly, or blow-fly Feeding mechanisms leading on to growth, reproduction and development.	Various species of caterpillars available on cabbage, etc , until end of October	Collect caterpillars Observe feeding mechanism, pupation Compare with life-history of blow-fly or fruit-fly
* (5)	5 The seed and its germination. Conditions for germination		Dissection of soaked bean seeds and others collected Grow in boiling-tubes, examining at intervals Experiments to show necessity of warmth, water and air, soil not necessary Control experiments
(3)	6 Responses of the seedling. Light and gravity.		Examination of typical seedlings bean, cress, any others brought in. Phototropism, etiolation and geotropism demonstrated by simple experiments

* Possible break for winter

YEAR I—BIOLOGY (*continued*)

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
(3)	7 Responses of insects and the frog. Light, contact and chemical stimuli.		Colour change in white butterfly pupae in coloured boxes Responses of caterpillars to contact stimuli Responses of Drosophila or blow-fly larvae and adults to light and food Conditions for colour change in the frog . background, moisture, warmth, light.
**			
(2)	8 Respiration of germinating seeds Production of heat and comparison with burning Carbon present in plant tissues		Germination of seeds in flask with lime-water , control with poisoned seeds *Thermos experiment with control* Char plant tissues
(10)	9 The Frog Life-history, mating and fertilisation The egg and its development Respiration in tadpole and adult frog Blood circulating in gills of tadpole.		Collect pairs of frogs during copulation period. Raise several lots of spawn, some in tanks by itself, some with carnivores (Dytiscus or Water-boatmen) Observe at frequent intervals Examine tadpoles with external gills under microscope Put into boiled water to show need for oxygen Demonstrate CO_2 production and O_2 uptake by adult frog
(4)	10 The Flower. Structure and func-		Examine one large flower and draw

** Break for hard weather of winter.

		tion Pollination, fertilisation and growth of seed.	parts Show other flowers brought in by pupils have similar structure Collect observations on pollinating agents in the field Germination of pollen grains in sugar solution
(2) Total 36	11	Honey Bee Social life Life-history , castes , adaptation of worker to its various functions.	*Observation hive if possible Feed bees on honey and water* Examine pollen from pollen baskets

(Item 9 must be done about end of February or early March)

ALTERNATIVE SCHEMES

	Frog	Flowering Plant	Insect
Structure	B (i) (*a*)	A (i)	C (i) and (ii)
Nutrition	A (vii)	A (vi)	—
Respiration	B (ii)	A (v)	—
Response to Stimuli	B (iii)	A (vi) (*b*)	C (iii)
Growth and Reproduction	B (i) and (iv)	D, A (ii)–(iv)	C (i)

The above table may be of assistance to those who wish to make other schemes, which may be necessary owing to local conditions or time-table difficulties Some may prefer to concentrate all the biology into the Spring term, others may wish to commence with Section C. In planning the work careful note must be taken of the seasonal considerations and consequent availability of material Some may prefer to read the above table horizontally instead of vertically, i e by dealing with one physiological process (e g. respiration) at a time with all three organisms, thus making a kind of comparative study of the activities of living organisms. By this method, however, one loses the view of each organism as a complete individual, each possessing the characteristics of a living organism. This important biological consideration is more readily impressed at this stage, when one's consideration of processes and functions is more elementary in nature, than later when a more comprehensive study occupies a much longer period.

B. CHEMISTRY

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
	I INTRODUCTION.		
(5)	Might include an informal study of some common substances, e g action of water and heat on salt, sand, chalk, sulphur, nitre, blue vitriol, coal, etc , leading to first ideas of solution, crystallisation, filtration, fusion, chemical change, etc	One suggestion for tackling the start of laboratory work in Chemistry. Many other approaches are possible	Heat various substances in $3'' \times \frac{1}{4}''$ test-tubes Experiments on solubility, filtration and evaporation (Purification of rock salt is quite good) *Crystallisation of sulphur from carbon disulphide.* *Crystallisation of sulphur from a melt* Separation of sand and salt (or other mixture containing one water-soluble constituent)
	II COMPOSITION OF AIR		
(12)	One of the first problems of the Chemist—to find out what substances are made of Analysis Living things and burning substances use air. Combustion of		Burn candle, coal, wood in free air supply and under gas-jars (or jam-jars of different sizes) *Analysis of air by burning phosphorus in air over water (or in R B flask)*

	candle, wood, coal in free and in limited supply of air (not over water) Analysis of air by burning phosphorus in air, by slow combustion of phosphorus and (optionally) by alkaline pyrogallol.		Analysis of air by use of alkaline pyrogallol or phosphorus *Separation of nitrogen by passing air over heated copper*
	Nitrogen.		
	The inert gases and their uses		
	Rusting of iron, (*a*) uses 1/5th of air, (*b*) both air and water necessary.	Treated as a small research problem.	Experimental investigation of conditions for rusting of iron. Function of CO_2 can be omitted at this stage.
	Protection of ironwork.		
	Air dissolved in water—its biological significance Presence of CO_2 and H_2O in air.		Collection and analysis of air expelled on heating tap water. Show presence of CO_2 and water vapour in the air
	Oxidation of iron, lead, copper, magnesium and mercury. Increase in weight on oxidation of metals		Gain in weight of metals on heating in air *Heat mercury in air.*
	First ideas on elements and compounds	Use simple examples of elements and compounds in everyday use.	
	III. OXYGEN		
(8)	Small-scale preparation from mercuric oxide		Heat mercuric oxide in 3″ × $\frac{1}{4}$″ test-tubes
	Larger scale preparation from potas-	Or heating potassium	Preparation of oxygen by heating

YEAR I—CHEMISTRY (*continued*)

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
	sium chlorate and manganese dioxide (catalyst).	permanganate could be used	potassium chlorate and manganese dioxide (Use small-scale apparatus—e g , as that described in *S S R*, **76** (1938), p 592)
	Oxygen in cylinders from liquid air. Properties of oxygen leading to products of combustion of sulphur, phosphorus, carbon, sodium, magnesium, calcium and iron Action of water and litmus on these products Action of lime-water on carbon dioxide	No details of isolation	Combustion of sulphur and carbon in oxygen Action of water and litmus on products Action of lime-water on carbon dioxide Combustion of *phosphorus*, *sodium*, magnesium, *calcium* and iron in oxygen (from cylinder) A Rose crucible is useful for calcium Action of water and litmus on products
	Acids and alkalis Reference to some common acids (sour taste) and alkalis	Include phosphoric acid and the phosphates	General properties of acids (use citric acid) and alkalis (use sodium hydroxide. Examine other acids, e g tartaric, hydrochloric, nitric and sulphuric, and alkalis, e g. calcium hydroxide, ammonia
	Preparation of salts by neutralisation, evaporation and crystallisation	Use of pipette and burette not necessary at this stage	Preparation of salts by neutralisation, using litmus paper as external indicator. Different pupils to make different salts. (Avoid NH_4NO_3 !)
Total 25			

C. PHYSICS

INTRODUCTORY HEAT

(5) Effects of heating bodies get hotter, melting, evaporation, chemical action; burning, destruction of life; light; expansion.	While the treatment of the effects of heat must necessarily be brief, opportunity may be taken to emphasise the differences between melting and solution, to illustrate the three states of matter and to introduce the idea of ignition-point In the simple introductory experiments, no details of chemical action and tests are required. Emphasis only on heat assisting the formation of a new substance Brief reference could be made to Pasteur, pasteurisation, sterilisation, etc.	Melt paraffin-wax Dissolve paraffin-wax in Xylene (Xylol) *Heat ice, wax and sulphur until vapour formed Show ignition of wax and sulphur vapour without contact with flame* Action of heat on mixture of iron filings and sulphur. *Observe liquid from Hay infusion using micro-projector. Heat strongly and again observe* *Burn magnesium ribbon Hold a gas mantle in a non-luminous bunsen flame* Heat electrically a length of iron wire suspended between two stands
Expansion and contraction of solids, liquids and gases	One rod used by each set of pupils	Heat rods of iron, brass, copper, aluminium, invar, etc, of equal lengths while clamped at one end, the free end rolling a needle with

YEAR I—PHYSICS (*continued*)

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
			attached pointer. (If tubes heated by steam are used, expansions can be compared) *Bar and gauge or ball and ring.*
		Generalisation from collection of class results	Expansion of liquids Expansion of gases.
	Unequal expansion and contraction of solids and liquids		*Unequal expansion of solids. Compound bar.* *Unequal expansion of liquids.* *Equal expansion of gases.*
	Great force exerted during expansion and contraction -		*Force exerted during expansion and contraction Bar breaker* Heat 12″ strip of ply-metal clamped at one end with pointer fixed at the other end
	Effects, compensation for and uses of expansion and contraction. Invar, ply-metal and applications.		Heat ply-metal strip controlling electric circuit (bell, lamp, etc). *Flashing lamps. Action of control lamp*
	Thermostats	Regulo, gas bellows, ply-metal.	
(4)	THERMOMETERS.		
	Possibility of using expansion as a means of measuring temperature	Relation of scales not to be laboured.	Thermometers, C and F, used to measure the temperatures of tap

	Examination and use of mercury thermometer. C and F scales of temperature. Idea of relation between scales. Special kinds of thermometers clinical, maximum, minimum, rototherm Use of mercury, alcohol ; reasons against use of water	Possibility of introduction of experiments on Surface Tension Low B P. and high F P. of water No mention of expansion on freezing	water, mouth, hot water (finger test) and boiling water Graduation of test-tube thermometers (Stoppered tube carrying a narrow quill tube and containing coloured water Use mercury thermometer for comparison.) *Surface tension experiments to illustrate the ' skin effect '.* To illustrate the rototherm thermometer, heat a flat spiral of plymetal with one end clamped, the other end having a pointer attached
(4)	CONDUCTION AND CONVECTION Conduction Difference between conductivities of various substances, including liquids and gases	Heat sensitised paper.	*Heat conductivity in metals.* Copper bar heated at one end, the other end dipping into a beaker of water or holed for a thermometer. Nails or shot waxed to copper rod which is heated at one end Copper rod heated and cooled while lying on heat-sensitised paper. Hot water poured into thin and thick copper vessels held one in each hand

YEAR I—PHYSICS (*continued*)

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
			Comparison of conductivities by thin wires of copper, brass, iron, etc., placed fan-wise on heat-sensitised paper and heated at the junction Metal rod held at bottom and heated at top Repeat with test-tube of water
		Conduction in gases difficult to demonstrate simply	Comparison of heat conductivities of mercury and water
	Uses of good and bad conductors.		Two-inch length of copper wire held in hand and heated at the other end by a match held in the free hand
	Heat insulation		Paper wrapped round rod of wood and brass and heat applied at the junction Heat applied to paper covering pattern of metal screws in wooden board
	Davy Safety Lamp		*Davy Safety Lamp.* Copper spiral extinguishes a candle flame Experiments with gauze and bunsen.
	Convection currents in liquids.		*Convection currents in liquids* Small flame heats beaker or flask containing small balls of blotting-

	Hot-water system Ocean currents Cooling systems		paper, paper fibre, sawdust or potassium permanganate crystals Half-inch nichrome coil (26 S W G) heated electrically (12 v) in trough of water containing crystals of potassium permanganate Cold-water currents using ice or solid carbon dioxide. *Convection tube* *Model hot-water system.*
	Convection in gases Ventilation Winds Factors affecting loss of heat by bodies.		*Convection currents in gases* *Lamp-glass over candle and ' T ' piece of metal* *Smoke-box fitted with chimneys.* Rotating vaned wheel and paper or metal spiral *Convection currents produced in air by bunsen and ice or solid carbon dioxide (projection).*
(4)	**INTRODUCTORY LIGHT.** General association of Light and Heat Vision Non-luminous bodies seen by scattered light Beam through water-tank Straight-line propagation Pinhole camera	Narrowing of beam leads to idea of rays.	Parallel beam of light passed through glass tank containing water. Beam then made visible by chalk dust, fluorescein, etc *Scattering of light demonstrated by ' sunset ' experiment.* Pinhole camera.

YEAR I—PHYSICS *(continued)*

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
	Shadows from point and extended sources Eclipse of sun and moon Contrast with phases of moon		*Shadow effects produced by obstacle placed in beam of light from point and extended sources Plain screen replaced by holed screen and shadow produced viewed through holes*
(4)	REFLECTION PLANE MIRROR. Regular reflection as opposed to scattering Experiments with beam apparatus leading to $i = r$, position of object and image leading to $v = u$, image size equal to object size and lateral inversion. Discussion and simple examples.		Experiment with beam apparatus leading to angle of incidence equals angle of reflection Lateral inversion (watch, letter F, etc , held in front of plane mirror). Image of letter L drawn on paper and in front of plane mirror.
	Periscope		Action of periscope using vertical board and beam apparatus *Plane sheet of glass used to obtain image of unseen object (candle burning in water, Pepper's Ghost).*
(2)	COMPOSITE NATURE OF WHITE LIGHT. Dispersion of white light by prism, spectrum	See Modern Science Memoirs, No. 13	Production of spectrum, further deviation by second prism and recombination of colours by inverted prism

	Colour by absorption and reflection		Reflect beam of white light from surface of thick coloured glass Examine images produced by reflection at front and back surfaces
	Additive and subtractive colour effects.	Leads to idea of primary colours	Use of filters and spectrum to analyse light of different colours Colour discs. Addition of primary colours
			Absorption effect with different transparent materials *Effect of change of incident light on colour of a surface*
(6)	INTRODUCTORY ELECTRICITY AND MAGNETISM		
	Elementary treatment of sources of supply Generation and storage	Illustrate electrical energy from chemical energy. Idea of D C	Break down torch battery Use zinc and carbon in sal ammoniac solution with 1 5-v. lamp Repeat with copper and zinc in sulphuric acid Idea of current direction using centre zero ammeter and reversing cell connections
	A C. and D C.	Idea of A C.	*Use D C and A C dynamos to light lamp Centre zero ammeter shows D.C and A C effects.* Light lamp by accumulator Centre zero ammeter to show D C.

YEAR I—PHYSICS (*continued*)

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
	Idea of conditions for current flow (electron drift, if desired) Insulators and conductors. Electrical pressure differences (potential difference), E M F. Control of current flow Switches	Storage of electrical energy by chemical action	*Break down old accumulator (or use model)* Build up model of lead plates in acid Show need for charging and colour changes produced during charge and discharge Voltmeter used to measure ‘ driving power ’ of various cells and batteries Use simple circuit to show variation of P D round it while current remains constant Preparation of a list of insulators and conductors using common substances
	Property of resistance and idea of variable resistance		*Circuit containing lamp or ammeter Change of current shown when* (*a*) *Wires of different materials and same cross-section and length are included* (*b*) *Wires of same material and same cross-section but of different lengths are included* (*c*) *Wires of same material of equal lengths and different cross-sections are used*
	Setting up of simple circuits using		Set up simple 2-volt circuits

	flash-lamp bulbs to illustrate the above ideas.	Effect on brightness of lamp may be discussed	(*a*) One lamp, one switch (*b*) Two lamps using one switch (series and parallel) (*c*) Two lamps using two switches (independent control). (*d*) Two two-way switches to light one lamp (staircase lamp).
	Working of electric bell. Description and analysis	See *S S R.* **104** (1946), p 68	*Metre rule electric bell.*
	Action of bell solenoids on iron and steel compared with action on other metals. Magnetic attraction Magnetic properties of iron and steel established by these metals when used as cores of solenoids. Study of temporary magnets Chucks, scrap separators, brakes, self-starters, signals, telegraph, relay, etc. Study of permanent magnets Attraction at poles shown by testing lift on iron filings and on soft iron Indication of N pole by floating or suspended magnet. Action of like and unlike poles by balancing magnet or by floating or suspended magnet		Permanent magnet (*a*) Prepare a list of magnetic and non-magnetic substances. (*b*) Rolling iron filings for poles and distribution (*c*) Suspended magnets indicate N and S pole (*d*) Law of repulsion after identification of poles in above.
Total 29	The Navigator's Compass The Earth's N Pole as a magnetic S pole		*Model of Earth and external field to show action of compass needle.*

YEAR II

A. BIOLOGY

This year is mainly devoted to the relationships of animals and plants to the air (gases of the atmosphere are studied in the Chemistry Section) The energy principle is introduced, also the dependence of animals and plants on each other. However, at the beginning of the autumn term seeds and fruits are abundant and could conveniently be studied as a conclusion of the work on the flower done in the previous term (Methods of seed dispersal show adaptation principle.)

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
(2)	A. (i) Fruit and seed dispersal		Study and draw stages in one type, e g sweet pea, tomato and a few selected dispersal examples
	II. THE PLANT IN RELATION TO AIR.		
(8)	A. Gaseous exchange CO_2/O_2 Photosynthesis—light, CO_2 and chlorophyll necessary. Respiration in plants		*Experiments to show* CO_2 *and heat given out.* (More or less repetition of Year I experiments) *Oxygen and carbon compounds used up* Experiments to show starch formation in light and CO_2 and chlorophyll required.
(2)	B. Transpiration		Bell-jar experiment Cobalt chloride experiment
(2)	C. The Carbon cycle.	All life depends on the energy of the sun which is used to reduce CO_2 and the carbon is combined	

		with other substances absorbed by plants to produce food stores.	
	III. ANIMAL FOOD—THE SOURCE OF THEIR ENERGY.		
(4)	A Carbohydrates, proteins, fats, mineral salts, vitamins, water		Tests for carbohydrates, starch (iodine), reducing sugar (Fehling or Benedict), fats (grease-spot, osmic acid, extraction with ether), proteins (one test, e g Millon's), vitamin A (antimony chloride in chloroform) Use these tests for common foods
(2)	B Story of the discovery of vitamins.		
	C Balanced diet Uses of the various foods		
(2)	Needs of child and adult (Meaning of statement that heavy worker needs 4,500 kilocalories a day)	Chemical basis of this work will at this stage be very imperfectly understood	
	IV. RESPIRATION AND THE RELEASE OF ENERGY		
(4)	A Respiration of land animals (Man) Lungs Detailed structure		*Demonstrate the sheep's heart and lungs. Slide with capillaries injected*
(3)	B. Blood, its relation to O_2 and CO_2 transport Change of colour with and without O_2. Clotting of blood Fibrin and serum.	Any mammal may be discussed here Emphasise way in which blood transports O_2 to and CO_2 from *every cell* in which respiration occurs and that this oxidation process releasing energy is going on continuously in every cell.	Ox blood and sodium citrate Reduction with sodium hyposulphite
(3)	C Mechanism of breathing Diaphragm and muscles of thorax.		*Demonstration model with small balloon in bell-jar with stretched rubber base*
Total 32			

YEAR II—(*continued*)

B CHEMISTRY

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
(8)	IV WATER.		
	Local water (or sea-water and its impurities) purification by distillation.		Evaporation of tap (or sea-) water. Distillation of water—use of simple condensers. (It is not difficult to devise simple condensers for class use)
	Action of water on substances, e g. salt, blue vitriol, anhydrous copper sulphate, potassium, sodium, calcium, magnesium, zinc, copper	First ideas of activity series arise from this	Action of water on such substances as sodium chloride, hydrated and anhydrous copper sulphate, anhydrous cobalt chloride, calcium, magnesium, zinc, copper. *Action of water on sodium and potassium*
	Efflorescence and deliquescence.		Experiments on efflorescence and deliquescence
	Distinctions between physical and chemical actions, with energy changes in chemical actions	Show production of heat, light, sound, electricity, etc , during chemical changes.	*Physical and chemical changes*
(12)	V. HYDROGEN.		
	Preparation of hydrogen (*a*) from cold water, (*b*) from steam (including reversible reaction with iron), (*c*) by replacement from acids	Link with activity series discussed in Section IV.	Preparation of hydrogen by action of water on calcium Action of steam on heated magnesium (Simple apparatus for this is given

		in *S S R*, **84** (1940), p 1143, and **98** (1944), p 95) Action of steam on heated iron and copper (Can be done in narrow pyrex tubing, using reduced iron or copper powder) Reduction of iron oxide by hydrogen Action of acids on metals. Preparation of hydrogen by action of dilute acid on zinc (small scale). (Not too much smelling !—danger of arsine from commercial zinc)
Properties of hydrogen, including density and diffusion First ideas of molecules leading to surface phenomena and Brownian motion	Qualitative aspect only. Rates of diffusion by porous pot connected to manometer Diffusion in liquids and gels	Properties of hydrogen *Divisibility of matter* *Experiments to illustrate molecular motion* *Brownian motion* (A smoke cell can be made from glass slips and plasticine)
Burning of hydrogen to form water, an oxide of hydrogen. Synthesis as opposed to analysis Reduction of an oxide by hydrogen	Give simple ideas of oxidation and reduction.	*Synthesis of water by burning hydrogen* *Action of hydrogen on heated copper oxide*
Preparation of zinc sulphate—a salt by replacement of hydrogen from an acid		Preparation of zinc sulphate (from hydrogen preparation above)
Analysis of water by electrolysis		*Electrolysis of water*

	Densities of solids and liquids using spring balance	Class results collected	Densities of various solids (cubes). Densities of various irregular solids by displacement (sink floating bodies by sinker or knitting needle). Densities of various liquids including water. Density of a gas.
(8)	PRESSURE IN LIQUIDS. Meaning of pressure Distinction between pressure and thrust Characteristics of fluid pressure Transmission equally in all directions Measurement of pressure in liquids		Weights placed on rectangular wood block (faces of different areas), sink block to different depths in warmed plasticine, moist sand, etc Pressure in liquids Gas-jar cover-glass held against end

		of wide glass tube when forced downwards into water Bung carrying tapered quill tube placed in glass tube 'Fountain' produced when jet held below water-level. *Pressure in liquid acts equally in all directions.*
Pressure at house taps, etc. Importance of vertical height Experiment on balancing columns in 'U' tube Effect of size of tube.	Pressure transmitted by mercury leads to idea of pressure transmitted by air and so to manometer.	*Increase of pressure with depth* *Pressure independent of area* *Pressure depends on 'head' of liquid.*
Measurement of pressure in gas mains by water manometer (mention Bourdon gauge).		Water finds its own level *'U' tube with different diameter limbs* *Columns of different liquids in 'U' tube, separated by mercury index.* Comparison of densities of different liquids by 'U' tube method
Hydraulic press and Hydraulic garage lift.		Hydraulic press *Drawing-board on rubber tyre or hot-water bottle connected to vertical glass tube containing water.*
		Pressure of the atmosphere Collapsing

YEAR II—PHYSICS (*continued*)

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
			Gas-jar pushed mouth downwards into water Rubber sucker Card and tumbler
			Water-jet in test-tube
			Burette full of water inverted in beaker of water; air admitted later
	Barometer considered as a 'U' tube.		*Barometer tubes of different lengths inverted in mercury trough.*
	Aneroid barometer. Altimeter		*Balloon containing a little air under bell-jar connected to exhaust pump* *Variation of height of barometer with pressure change.* Measurement of air pressure directly using weight and bicycle pump. Aneroid barometer model
(3)	RADIATION. Effect of surface on radiation and absorption.		Heat source (bunsen) at equal distances from and between polished and blackened 'tin' plates having thermometer holders at the back of the plates
			Thermometers in similar cans with

	Radiant heat shown to obey same laws as light Applications High-temperature thermometry Thermos flask as basis of revision of modes of heat transference.		black and polished surfaces and equal amounts of hot water added Brass rods drilled to fit thermometer and heated to 100° C by bunsens (polished) and by candle (blackened). Times taken to cool over 100–80° C *Comparison of behaviour of radiant heat and light* *Rectilinear propagation* *Speed Using electric light bulb as emitter and boy as observer* *Reflection Using electric fire as emitter and boy as detector after reflection from sheet of tin* *Focusing*
(4)	Units of Heat Distinction between heat and temperature Experiments on heating different quantities of water by same source for given time to give idea of quantity of heat and the distinction between this and temperature Discussion of unit of heat Calorie Kilogramme-calorie. Calculation of heat required to raise the temperature of a given quantity of water a given amount.	Idea of the need for units should be stressed The unit can be derived from this experiment	Temperature rise noted when white-hot platinum wire and warmed iron ball are dipped in equal quantities of water Heat different, but simply related, quantities of water by the same source (bunsen or immersion heater) for the same time and note temperature rises

YEAR II—PHYSICS (*continued*)

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
	Rough determination of the calorific value of paraffin-wax. The B Th U. and the Therm. Simple calculations as with the calorie		Heat known mass of water in a thin can by means of a candle on a watch-glass using a draught shield. Temperature rise and difference in weight of candle noted (Meta fuel burned on wire gauze could replace candle)
(9)	CHANGE OF STATE. Discussion of what happens to heat supplied to boiling water Idea of latent heat. Evaporation Cooling evaporation		Water heated by steady source and steady rise of temperature to 100° C. noted Effect of ether evaporating on hand and of water evaporating on cotton-wool placed round thermometer bulb.
	Sweating, refrigeration.		*Evaporate ether in can on wooden block with water film under can until freezing of water takes place* *Milk coolers (one varnished on the outside and the other untreated) contain water, temperatures being noted at intervals*
	Vapours Saturation Molecular explanation of phenomena	Mention of superheating.	*Invisibility of water vapour demonstrated by passing steam through heated copper spiral*
	Ideas extended to atmosphere Condensation, clouds, fog, etc.		*Hot steam detected by charring effect on paper.* *Vapour-pressure fountain.*

		Saturation and conditions for drying *Cooling by expansion Bulb of air-mercury index thermometer enclosed in Winchester bottle* *Bicycle valve in bung of bottle enables pressure to be increased and then decreased suddenly Movement of mercury index indicates cooling effect* *Air pumped into Winchester bottle by bicycle valve in bung Water in bottom of the bottle saturates air inside Formation of cloud in bottle when bung pulled out.*
	Humidity Hygrometers and hygrometric state Conditions for drying Importance of cooling effects on human body Conditioning of air in buildings and its industrial importance.	Determination of dew-point using polished can cooled by evaporation of ether or by adding ice *Hair Hygrometer*
(10)	INTRODUCTORY ELECTRICITY AND MAGNETISM	
	Declination Application to navigation.	*Model of earth and external field to show declination.*
	Making magnets by stroking	Magnetise clock spring by single touch, testing effect on boot sprigs after a given number of strokes up to saturation Break and test one-half of the clock spring

YEAR II—PHYSICS (*continued*)

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
			Heat the other half to redness and test
	Electrical method best for making magnets Rule for polarity		Magnet made by A C and D C solenoids Test with compass needle to deduce the rule for the polarity of the solenoid
	Induced poles in soft iron Attraction of neutral iron by induction		Magnetic induction in a bar of soft iron held near a strong magnet tested by boot sprig attraction and poles determined by compass needle Mutual repulsion of two needles attached to one pole of a magnet. Test laboratory stands for magnetisation and hammer a bar of iron in the Earth's field.
	Magnetic fields. Shielding		Plot various magnetic fields using iron filings Plot the magnetic field of a bag magnet and a solenoid, using compass needles Magnetic screening.
	Destruction of magnetisation heating, rough usage and A C solenoid Breaking of magnet as approach to		*Destruction of magnetisation using a nickel pendulum and A C solenoid* Illustration of magnetic theory by

	molecular hypothesis and idea of molecular magnets Possibility of explaining observed effects in terms of this hypothesis Test of this using a solenoid round a box of compass needles and glass tube of iron filings. Limitations of this hypothesis Electric current as something in a wire producing magnetic effects outside it. Straight wire effect. Other effects of electric current Heating demonstrated by fuse wire, lamp, immersion heater, electric fire, etc. Discussion of domestic arrangements.	use of test-tube of iron filings and collection of compass needles Demonstration of other effects of electric current Demonstration of heating effect Fusing current in different lengths and thicknesses of fuse wire (tin foil, radar tape, etc) Field surrounding straight wire, circular wire and solenoid (rule for polarity), by iron filings and compass needle.
	Chemical effects treated simply	Passage of current through liquids List of conductors and insulators and observation of other effects. (Use A C. and D C) Passage of current through solutions of metallic salts (Use A C and D C) Electrolysis of water. Test gases (A C and D C) *Electroplating and electrotyping*
Total 36		

YEAR III

A. BIOLOGY

The continuation of the matter-energy principle and the mechanism by which food reaches the cells for oxidation and growth, thus introducing some of the ways in which energy is utilised in movement and response to stimuli, the latter again exemplifying adaptation to environment, especially plant tropisms (para VIII).

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
(14)	V DIGESTION AND ABSORPTION IN MAN (MAMMAL) OR FROG.		
	A Alimentary canal and the uses of its various parts	Hygiene aspects should not be neglected	*Demonstrate with rabbit or other mammal Dissection of the digestive system and thorax cavity* Note differences from man
	B Blood as transporting fluid for digested foods, heat, etc		*Show (by injected slides as well as dissection) abundant blood supply to wall and villi*
	C. Digestion	Essentially the breakdown of large molecules by means of enzymes	Ptyalin on starch under various conditions to show characteristics of enzyme action. Pepsin on egg albumen Rennin on milk Emulsification of fats by alkalis (NaOH solution on olive oil in water)
	D. Absorption by blood capillaries Lymph		Lipase on fats Oily seed ground up with litmus. *Experiments on diffusion*

(6)	VI TRANSPORT BY THE BLOOD IN MAMMALS. The heart and general circulation. Arteries, veins, capillaries The heart as a force pump. Differences in structure of arteries and veins	Include figures of amount of blood, work done by heart, etc	*Dissection of sheep's heart Demonstration of aorta, vena cava, pulmonary artery and vein Circulation in web of frog's foot*
(6)	VII. EXCRETION IN MAMMALS Uses of liver (bile, urea, etc), kidney, positions of these organs in body The skin, sweating and temperature control Importance of suitable clothes and ventilation (Refer to CO_2 from lungs)		*Dissection of rabbit or any mammal primarily for heart and blood-vessels and urinogenital system. (If possible, indicate with opposite sex) Slide of skin section*
(9)	VIII ANIMAL AND PLANT MOVEMENT IN RESPONSE TO STIMULI Structure of typical limb, arm, muscles and nerves Simple reflex actions Structure of eye. Responses of seedlings to light, gravity and water Plant hormones (auxins) The ear (no detailed structure).	Arm muscles, biceps and triceps only.	*Demonstration of animal skeleton* Experiments on photo-, geo- and hydrotropisms Effect of lanolin paste of auxin on stem of seedling.
Total 35			
B	CHEMISTRY		
(5)	VI LIMESTONE, and other forms of calcium carbonate Origin, action of heat and acids		Action of heat and acids on calcium carbonate.

YEAR III—CHEMISTRY (*continued*)

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
	Quicklime, slaked lime and lime-water Synthesis of calcium oxide and of chalk		*Collection of carbon dioxide from heated calcium carbonate* Slaking of lime Preparation of lime-water *Synthesis of calcium oxide and calcium carbonate.*
(14)	VII CARBON DIOXIDE Preparation and properties · density, acidic solution, reaction with magnesium, action on lime-water and sodium hydroxide		Preparation of carbon dioxide by action of dilute hydrochloric acid on calcium carbonate (small scale) Properties of carbon dioxide Burning magnesium in carbon dioxide
	Carbon dioxide in daily life . fire extinguishers, fruit preservation, effervescent powders, aerated waters, refrigeration Solution of gases in water, effect of pressure		Preparation of effervescent powders *Fire extinguishers using carbon dioxide*
	The carbonates. Preparation by precipitation (as example of method of preparing insoluble salts) Preparation of other salts from carbonates		Preparation of carbonates by precipitation Preparation of other salts from carbonates.

Acids, bases and salts (including soap) General properties of acids and bases Methods of preparing salts . (*a*) action of acid on metal, (*b*) neutralisation, (*c*) action of acid on insoluble base or carbonate, (*c*) precipitation	Use of burette and pipette can now be introduced Also indicators other than litmus.	All methods of salt formation given in the syllabus
Carbon monoxide by reduction of carbon dioxide with carbon Its poisonous nature Burning of carbon monoxide Reducing properties.	Stress dangers of carbon monoxide poisoning in everyday life Refer to Biology, Section IV	*Preparation of carbon monoxide from carbon dioxide and carbon Carbon monoxide as a reducing agent* *Action of carbon monoxide on citrated blood*
VIII NATURAL RESOURCES OF THE EARTH		
Coal Its origin Products of combustion Destructive distillation of coal and wood , charcoal, coke, tar, aqueous liquid, gas The gas works	Very simple treatment Stress economic importance of coal This is an appropriate time to show that carbon is an essential element in all living matter.	Destructive distillation of coal and wood.
Flame and explosion The Bunsen burner. Structure of flames and their coloration Gas/air mixtures.	See *S S R*, **74** (1937), pp 173–81.	Experiments on the Bunsen burner—flame structure, lighting back, etc *Combustion of coal gas/air mixtures.*

YEAR III—CHEMISTRY (*continued*)

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
	Explosions in mines and internal combustion engines ; oxidation releases energy	Link with Physics	
	Mode of action of fire extinguishers.	Point out different methods of extinguishing fires—cooling, exclusion of oxygen. Precautions in use of fire extinguishers	*Fire extinguishers.*
	Petroleum (Fractional distillation) Natural gas, petrol, paraffin, vaseline, paraffin-wax	Demonstrate with simple binary mixture and fractionating column. Details of chemistry of petroleum products not required	*Fractional distillation of, e g alcohol-water mixture.*
	Prevalence of elements in the earth's crust	Simple minerals Necessity for conservation of natural resources. Economic importance of sea-water.	

	Silicon, silica, silicates. Reduction by thermit process Glass and water-glass		Thermit reduction Silica garden. (Use jam or paste jars, NOT beakers)
(9)	IX. WINNING OF METALS FROM THEIR ORES (Confined to oxides) Reduction by (*a*) hydrogen, (*b*) carbon (charcoal block), (*c*) carbon monoxide	Very simple treatment of industrial methods of obtaining a few common metals, e g tin and iron.	Reduction of copper oxide by coal gas *Reduction of iron oxide by carbon monoxide* Reduction of oxides on charcoal block
	Oxidation and reduction related. Distinctive properties of metals	Link with Physics	
	Displacement of one metal by another Activity series	Link with Sects IV. and V	Displacement of metals from solutions of salts (Use drops of solution There are some useful notes in *S S R*, **94** (1943), pp 262–72)
	Alloys, including low-melting alloys	Confine attention to a few common alloys, e g. brass, bronze, solder, duralumin, Mg alloys, Wood's metal, etc.	
Total 40	Mixtures—variable composition		

YEAR III—(*continued*)

C. PHYSICS

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
(4)	INTRODUCTORY WORK ON FORCE AND WEIGHT		
	Types of forces. Weight, tension, thrust, friction, etc.		Types of forces
	Measurement of forces by extension of spring		Graduation of spiral spring and its use to weigh objects
	Graduation of spring balance (mention of Hooke's Law and elastic limit, application to wires, etc)		
	Experiments with dynamometers. Tension in cord, cord passing over fixed pulley (change of direction)		Experiments with dynamometers.
	Friction of block on table		Simple friction experiments
	Balancing parallel forces Sum of forces nil		Experiments on balancing of parallel forces
(3)	LEVERS AND MOMENTS.		
	Study of levers leads to moments. Experiments leading to $P a = Q b$ Moments Law of moments Examples of levers		Measurement of turning power of a force Simple lever verification of law of moments and/or weight of body using moments.

(2)	CENTRE OF GRAVITY AND STABILITY Meaning and experimental determination.	Determination of centre of gravity, using plumb-line
	Movement of C G with additional load. Elementary ideas of stability and applications	Determine C G of triangular lamina Fix weight by means of plasticine at point on median Find the new C G Move weight and find new C G Equilibrium states, using rectangular block, cone, ball, etc Rectangular block with plumb-bob fixed on one face on horizontal line through C G and placed on drawing-board which is tilted Weight hanging from jaws of clamp attached to stand on drawing-board Angle of tilt noted before toppling for various heights of weight *Collection of C G apparatus, toys, etc, to illustrate principles of equilibrium.*
(7)	ARCHIMEDES' PRINCIPLE AND FLOTATION Upthrust in liquids Archimedes' Principle	Upthrust in liquids Verification of Archimedes' Principle (bucket and cylinder, test-tube, etc). Downward reaction on vessel containing liquid equals upthrust, using compression balance.

	Flotation, simple hydrometer. Effect of density of liquid on volume of body immersed. Simple calculations on volume displaced Applications of hydrometry Flotation of ships, Plimsoll line Airships and balloons , lifting power Charging of batteries, testing of milk, etc.		Relative densities using Archimedes' Principle *Experiments on flotation and Cartesian diver* Hydrometers. Construction and use of drinking-straw hydrometers
(3)	BOYLE'S LAW AND PUMPS. Boyle's Law experimentally (no graphs). Simple calculations. Meaning of Law.		*Relation between pressure and volume of a gas* Verification of Boyle's Law Pressure of water mains using Boyle's Law *Syringe.*
Total 19	Force and lift pumps. The human heart as a pump. Methods of reducing and increasing pressure. Filter pump		*Force pump* *Lift pump*

YEAR IV

A. BIOLOGY

The study of other organisms of economic and medical importance to man, followed by a study of the soil as the basis of the organisms' environment

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
	IX BACTERIA AND FUNGI AS AGENTS OF DECAY AND DISEASE		
(4)	A Penicillium. Mucor. Yeast. Brewing and bread making Anaerobic respiration		*Cultures and slides (micro-projector and lantern) Cultivation of moulds on agar-agar slopes* Need for sterilisation. Yeast Fermentation of sugar (Link with Chemistry) Exposure of agar-agar plate to air Potato-water experiments to show conditions favourable to bacterial growth.
(6)	B. Bacteria The work of Pasteur and Lister Immunisation Viruses Action of blood in destruction of disease bacteria Phagocytes Antiseptics and antibiotics (penicillin)		
(2)	C Food preservation Methods Refrigeration, canning, etc. Milk pasteurisation and sterilisation		
(2)	D Insects as carriers of disease.	Mosquito and house-fly, excluding Plasmodium life-history	

YEAR IV—BIOLOGY (*continued*)

PERIODS	CONTENT	COMMENTS	PRACTICAL WORK
	X THE PLANT IN RELATION TO THE SOIL		
(5)	A Osmosis Absorption and transport of water Culture solutions Importance of phosphates, nitrates, potassium, iron and magnesium Artificial fertilisers Farmyard and stable manure. The compost heap	Make clear distinction between osmosis and diffusion	Potato experiment Thistle funnel experiment Examine root hairs Capillarity experiments *Root pressure experiment* Passage of water through wood *Water culture experiments* Experiments if possible in school garden
(6)	B The soil Origin and properties Sandy and clayey soils Loam Comparison of properties		Suspension of soil in water Partial separation of sand, clay and humus *Demonstration of mineral salts and living organisms* Compare percentages of water in sand and clay when saturated and when plant wilts in them Clay cracking on drying Permeability of sand and clay to air and water
(3)	C Bacteria in the soil Decay. Nitrogen cycle Leguminous plants and their importance in agriculture	Four-course rotation.	*Bacterial nodules in pea and clover plants. Demonstration of bacterial colonies from soil-washing on agar plate Microscope slide of nodule*
(2)	Crop rotation and ley farming Grasses more important crop as source of meat, milk and means of restoring humus content of	Scientific methods of grass preservation—dried grass, silage. Recognition and life	Raise plants in pots or in school garden Record approximate rates of multiplication in each generation.

	soil Cereals—barley, oats, wheat	cycle of wheat, oats, barley	
(2)	D The earthworm and its importance in soil fertility		*Wormery Dissection to show alimentary canal only*
Total 34	Effect of plants on soil Erosion		

B. CHEMISTRY

(8)	X COMMON SALT		
	Extraction and purification by recrystallisation Saturated solutions	This Section should show that salt is a prime raw material to heavy chemical industry	
	Preparation of concentrated hydrochloric acid from salt		Preparation of concentrated hydrochloric acid from salt (small scale) Properties of hydrogen chloride gas (Demonstrate " Fountain " Experiment.)
	Chlorine by oxidation of hydrogen chloride		Action of oxidising agents on hydrogen chloride solution
	Combustion of substances in chlorine, including synthesis of salt Change in nature of elements on combination	Link with Sections V and IX Give chief differences between compounds and mixtures	*Preparation of chlorine Properties of chlorine. Combustion of elements in chlorine*

YEAR IV—Chemistry (*continued*)

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
		Revise air as a mixture and water as a compound	
	Uses of chlorine, e g bleaching, antiseptics Bleaching powder		*Preparation of bleaching powder* Bleaching coloured cloth by bleaching powder and hypochlorite.
(8)	XI Simple Electrochemistry		
	Electrolytes and non-electrolytes	Show that distilled water is a very poor conductor.	Electrolytes and non-electrolytes (Use A C and D C)
	Electrolysis of cupric chloride		
	Electrolysis of brine yielding hydrogen, chlorine and sodium hydroxide	Importance in manufacture of sodium hydroxide	General experiments on electrolysis (See *S S R*, **90** (1942), pp 172–8)
	Simple explanation of electrolysis in terms of ions.	Ease of discharge of ions as explanation of action at electrodes. Importance of H and OH ions in water (See *S S R*, **90** (1942), pp 172–178)	
	Electricity by chemical action Primary cells Depolarisation	Link with Activity Series	The setting up of simple cells Polarisation and depolarisation of a simple cell

	Secondary cells—reversible nature.		Making a simple accumulator with two lead plates in dil H_2SO_4
	Uses of electrolysis—electro-plating, extraction of metals, etc	Simple treatment of extraction of magnesium, aluminium and zinc	Extraction of zinc from zinc sulphate by electrolysis
(9)	XII. NITRE		
	Extraction of nitre Rough determination of solubility, including effect of temperature. Solubility curves	Use of chemical balance can be introduced here	Solubility of nitre in water Solubility curve of nitre
	Oxygen from nitre Nitric acid from nitre Uses of nitric acid and nitrates		Action of heat on nitre *Preparation of nitric acid*
	Explosives Decomposition of nitric acid by heat Synthesis of nitric acid by combustion nitrogen and treatment of product with water.	Link with relative ease of decomposition of nitrates	*Thermal decomposition of nitric acid*
(8)	XIII AMMONIA		
	Obtained from ammonium chloride Preparation of saturated solution Its basic properties Ammonium salts Oxidation of ammonia by (*a*) copper		Preparation of ammonia from ammonium chloride and calcium hydroxide Properties of ammonia and ammonia solution *The Fountain Experiment*

YEAR IV—CHEMISTRY (*continued*)

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
	acid. Reference to Haber synthesis of ammonia Importance of ammonium compounds	No plant details Use as example of increase of yield of a product by alteration of conditions of reaction	Liberation of ammonia from proteins Preparation of ammonium salts *Oxidation of ammonia by copper oxide* *Catalytic oxidation of ammonia*
	Nitrogen fixation	Link with Biology, Section X, C The story of Cavendish, Ramsay and Rayleigh as a good example of the use of the scientific method	
Total 33			

C. PHYSICS

(12)	INTRODUCTORY SOUND		
	Experiments to show sound is due to vibration and that a material medium is necessary for the propagation of a vibration		Experiments to show motion of a sounding body *Material medium is necessary for the transmission of sound*
	Experiments (with siren and other apparatus) to show the connection between pitch and frequency		*Connection between pitch and frequency*
	Limits of audibility Elementary discussion of waves (in rope or pond		*Limits of audibility (beat frequency oscillator)*

	for transverse waves. Medium vibrates but does not move as a whole) Longitudinal waves in air Experimental determination of velocity of sound in air (on field with stop-watch and pistol or cracker firework) Echo in air Echo in water Velocity in liquids and solids Applications : echo sounding, etc Stringed instruments ; dependence of frequency on length and tension (qualitative only as regards tension) Simple ratios of frequencies (octaves, thirds and fifths) Resonance The idea of resonance Air column above water in jar with tuning-fork Wind instruments : whistle, organ pipe, etc	$V = n\lambda$ can be introduced here (illustrated by reference to Radio Wave-lengths, e g in *Radio Times*	*Waves and wave properties demonstrated using ripple tank, wire spiral, wave machine, etc* Experimental determination of velocity of sound. Effect of medium on speed of sound Experiments with board and metre rule sonometer to show effect of length tension and type of wire Overtones by sonometer, using a feather Melde's experiment. *Resonance* Resonance of air column and tuning-fork
(6)	SPECIFIC HEAT Demonstration to show the difference between specific heats		Different effects of applying similar quantities of heat to the same masses of different solids and liquids.
	Simple determination by heavy vessels or other methods not involving a second specific heat Effect on climate, hot-water bottles,	Thin calorimeters will give results	Simple determinations of specific heats of solids and liquids using heavy vessels.

YEAR IV—PHYSICS (*continued*)

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
	hot pipes, water cooling systems of engines, etc. Simple calculations on specific heats.		
(8)	CHANGE OF STATE		
	Latent heat Rough determination of latent heat of steam Discussion and demonstration of latent heat of fusion of ice. Simple calculations of heat absorbed or evolved during change of state Simple consequences of high value of latent heats.		Idea of Latent Heat by heating ice and boiling the water formed Determination of latent heats of steam by heating water in a thin can, by passing steam through heavy vessels, etc Determination of latent heat of fusion of ice by heating ice in thin can, etc Plotting of a cooling curve
	Effect of pressure on freezing- and boiling-points Superheating Autoclave, pressure cookers, etc Change of volume on freezing Thermometer liquids Water thermometer (vice Hope's apparatus).	Refer back to expansion and water pipes	*Boiling water at reduced pressure* *Change of volume on freezing*
(3)	CURVED MIRRORS.		
	Curved mirrors as a means of focusing parallel rays Position of principal focus Caustic curve		Reflection of rays by concave and convex cylindrical mirrors
	Changes in size of image as concave and convex mirrors approach the		Simple determination of focal length of concave mirror (distant object).

	eye Uses of curved mirrors headlamps, searchlights, driving mirrors, shaving mirrors, etc		Changes in size and nature of image as mirror approaches eye along metre rule
(7)	REFRACTION Simple phenomena of refraction Variation with medium Snell's Law (intercept enunciation if preferred) Image by refraction Apparent depth Demonstration of internal reflection and critical angle Applications Use of prism as mirror.	Image of 2-v bulb can be made to coincide with image by reflection at surface Plastic rod may be used	Passage of a ray of light through a rectangular glass slab *Refraction* Relation between real and apparent depth (pin method, bulb or glass block) Some simple effects of refraction *Internal reflection and critical angle* *Some simple effects of internal reflection*
(9)	LENSES. Passage of light through prism Convex lens as a means of focusing rays	Can be demonstrated with cylindrical lenses on vertical light board.	The passage of light through a prism and that two similar prisms base to base bring light to a focus Effect with prisms apex to apex Action of lens in focusing rays
	Deviation at different parts of lens Focal length and its dependence on curvature Variation of nature, size and position of image as object approaches from infinity Real and virtual images Magnifying-glass Action of concave lens on beam of light Images by scale drawing. Magnification Focal		Deviation of rays at different parts of lens (Rotate lens in circle) Simple determination of focal length of convex lens Variation of nature and size of image as lens lifted from contact with printed page Determination of focal length of convex lens and magnification using simple optical

YEAR IV—PHYSICS (*continued*)

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
	lengths obtained from experimental results by scale drawing Effect of aperture Power of a lens		bench (metre rule etc) and illuminated object
(8)	OPTICAL INSTRUMENTS. The camera Meaning of f/11, f/32, etc. Effect of stop size The human eye , cornea, iris, pupil, lens, retina, optic nerve Comparison with camera Accommodation. Cause and correction of long and short sight Astigmatism and its correction Blind spot Persistence of vision Stroboscopy Dissection of animal's eye Lens arrangements in telescope and microscope Reflecting telescopes Binoculars and opera glasses Lantern Episcope Projectors Use of heat-absorbing glass and vapour lamps	Animal's eves are usually available from local butcher	*Dissection of eye of an animal* *Action of eye, defects of eye and their correction using model (large flask with suitable lenses fixed by plasticine)* Reversal of image on retina *Stroboscope using rotating disc with black and white sectors illuminated by neon lamp* *Optical illusions* Image of distant object thrown on glass screen with second lens to magnify it on a second screen Image viewed on removal of screens Set up two convex lenses as microscope and then as telescope Use concave and convex lens to form opera glasses
(3)	DISPERSION AND COLOUR. Colour defects of eye Mention of dispersion effects in lenses and achromatic lenses		*Colour fatigue*
Total 56			

YEAR V

A BIOLOGY

Man's conscious efforts to adapt himself to his environment was studied in para ix, and this idea of adaptation is confirmed by studies of adaptation to seasonal changes. An elementary treatment of evolution follows

A considerable amount of revision can be worked into the teaching. A simple study of heredity concludes the course

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
	XI. ADAPTATION TO THE SEASONS		
(8)	Adaptation to life-history (*a*) Plants Perennation Bulbs Corms Leaf fall Transport of substances to and from the storage organs Starch-sugar by plant enzymes (*b*) Animals Bird migration Hibernation Encystment (Amoeba)		Consider in class and examine and draw typical stages of a selected series Pupils to add others for themselves. Tests for food storage substances Maltase in barley
	XII ADAPTATION TO ENVIRONMENT —EVOLUTION.		
(6)	A Studies in any convenient habitat, e g pond or seashore, illustrat-	This summarises background work which	Visits to habitat Pupils bring in specimens for examination and

YEAR V—BIOLOGY (*continued*)

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
	ing ways in which organisms are adapted to life in that habitat particularly with reference to respiration, locomotion, reproduction, competition, food chains	has been going on throughout the course	discussion. Keeping selected organisms under observation
(6)	B. Study of plants and animals met with in the course of the above work, with a view to getting some idea of classification of animals and plants This will lead up to (i) a comparison of amphibia and land vertebrates (ii) the reptiles (legs, lungs, shelled eggs). (iii) birds (warm blooded, shelled eggs, feathers) (iv) mammalian reproduction (milk and nutrition of young). Pre-natal (placenta) and post-natal care. Temperature control		Illustrate in as many ways as possible in the various groups
(1)	C Same design of limb in land vertebrates		

(2)	D Elementary outline of fossil record and the formation of sedimentary rocks		Examine and draw specimens Visit, if possible, to geological exposure
	XIII Heredity.		
(6)	Breeding of dogs, horses, etc. Outline of Mendel's work with peas (Revision of pollination, seed formation, etc)		Breeding experiments, if possible, on Gammarus, Drosophila or mice. Failing this, obtain corn cobs
	Consideration of simple cross only Dominant and recessive		
Total 29	Human heredity Elementary outline of our knowledge.		
	It is suggested that the idea of the unique position of man in the animal kingdom should be developed in the course of this year's work	See Chapter 9 (" Some Special Considerations ")	
B	CHEMISTRY		
(8)	XIV. Sulphur		
	Sources of sulphur Oxidation to sulphur dioxide		*Oxidation of sulphur to sulphur dioxide.*
	Uses of sulphur dioxide—fumigation, refrigeration, etc.	Link with Physics	Reactions of sulphur dioxide (in solution).
	Catalytic oxidation of sulphur dioxide to sulphur trioxide.		*Oxidation of sulphur dioxide to sulphur trioxide.*

YEAR V—CHEMISTRY (*continued*)

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
	Preparation of sulphuric acid from sulphur trioxide.		
	General characteristics of a catalyst.	Revise details of catalysts already encountered. Extend to other commercial processes, e g hydrogenation, polymerisation, etc.	
	The acidic properties of dilute sulphuric acid and the dehydrating properties of concentrated sulphuric acid, e g. on blue vitriol, carbohydrates, etc.		Properties of concentrated and dilute sulphuric acid
(7)	XV. EQUIVALENCE.		
	Same weight of metal displaces same volume of hydrogen and combines with same weight of oxygen.		Determination of equivalent weights of magnesium, zinc and copper. (Simple methods are given in *S S R*, **84** (1940), p 1148) *Equivalent of sodium.*
	Law of Constant Composition. Development of theory of atoms and idea of valency	Stress invariable chemical properties of a compound	Analysis of copper oxide prepared by different methods. (Heating copper hydroxide, copper nitrate and copper carbonate. Analyse by coal-gas reduction)

(2)	XVI LAW OF CONSERVATION OF MASS Implicit in gravimetric work	The limitation of the law and the release of energy by destruction of mass should be noted.	Verification of law of conservation of mass
(20)	XVII CARBON The element (*a*) charcoal—adsorption, (*b*) graphite—lubricant, (*c*) diamond Allotropy The unique ability of the carbon atom to form complex compounds with large numbers of quadrivalent carbon atoms illustrated by the paraffins, cf. petroleum Organic compounds		Experiments on adsorption.
	Starch and sugar. Alcohol and acetic acid by enzyme action The production of ethyl (or amyl) acetate on test-tube scale Saponification—hydrolysis of oil or fat	Link with Biology, Section III	Experiments on starch and sugar. Preparation of alcohol by fermentation Preparation and hydrolysis of a simple ester Hydrolysis of fat
	Soap and glycerol Emulsions, colloidal solutions, smokes, etc ; cf true solutions	Keep to simple everyday examples of colloids.	*General properties of colloids*
	Soaps and other detergents.	Link with surface phenomena, Section V.	

YEAR V—CHEMISTRY (*continued*)

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
	Natural formation of hard water Fur and boiler scale Action of soap on hard waters Water softening		Experiments on hardness of water and its removal
Total 37			
C PHYSICS			
(6)	OHM'S LAW.		
	Idea of potential difference (water analogy). Ohm's Law illustrated by simple method		Pressure drop in wire Current in circuit constant Simple illustrations of Ohm's Law.
	Resistance Units International units of current Resistance and P D Connect unit of P.D. with that of cell	Defects of ammeter-voltmeter method stressed	Determination of resistance by (1) Voltmeter and ammeter, (2) Substitution
	Idea of E M F and internal resistance of cells	Effect of temperature on resistance by lamp experiment	Effect of temperature on resistance Determination of resistance of 4-v lamp when hot and when cold Internal resistance of cells and accumulator
(4)	INSTRUMENTS		
	Interaction of magnet and coil (or coil and soft iron)		Interaction of magnet and coil
	Moving-coil instruments Attracted iron and repulsion instruments Hot-wire instrument.		*Moving coil, moving iron and hot-wire instruments*

	Principles underlying multiple range instruments by shunts and bobbins Simple examples.	Verification of resistance formulae for series and parallel resistances.
(5)	ELECTRODYNAMICS	
	Action of magnet on current-carrying conductor Action of magnet on coil	*Interaction of current-carrying conductor (including liquid) and magnetic fields*
	Continuous rotation by commutator. D C motor. Value of more coils	Simple D C motor (reversal)
	Motors employing field coils, series- and shunt-wound A C motor	*Experiments with motor having field coil which may be used either in series or in parallel with armature coil Variation of speed with armature and field coil currents shown Effect of load (reversal).*
	Synchronous motor.	*Synchronous and attraction motors*
(5)	ELECTROMAGNETIC INDUCTION.	
	Elementary experiments to illustrate the production of an E M F	Elementary experiments to illustrate the production of an E M F. by induction
	Generation of current by rotating coil Simple A C and D C. dynamos	*Generation of current by rotating coil* *Simple generators.* *Dynamos fed with current to run as motors.*
	Eddy currents. Laminated armature. Back E.M F in motor. Starting resistance for motor.	*Eddy currents and their effects*

YEAR V—PHYSICS (*continued*)

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
(4)	ALTERNATING CURRENT.		
	Significance of A.C Refer back to simple dynamo Magnetic, heating and chemical effects of A C. Advantages and disadvantages of A C and D C	See Modern Science Memoirs, No 21	Revision of previous experiments to show heating, magnetic and chemical effects of A C
	Transformer, with practical details of construction		*Alternating current in transformer* *Ratio of transformer Iron losses* *Current consumption on open and closed secondary circuit.* *Production of high voltages and heavy currents.* *Thomson ring experiment*
	Induction coil.		*Induction coil.*
	Transmission of electrical energy.		*Transmission of electrical energy.*
(2)	TELEPHONE AND TELEGRAPH.		
	Action of Bell telephone Its drawbacks. Use of microphone Telephone circuits M C. loudspeaker.		
(8)	HEATING EFFECT AND ELECTRICAL ENERGY.		
	Experimental investigation of heating effect Energy as P.D. × Quan-		Dependence of heating effect on current and on resistance.

	tity H varies as E × I Power Power in electric lamp The watt (1 joule/sec) Calculations on wattage based on domestic supply. B of T Unit Tariff system Wattmeter as ammeter superimposed on voltmeter Electrical determination of mechanical equivalent of heat Lamps Fuses Arcs Furnaces Welding, etc.	Experimental investigation of heating effect (low-resistance coil in beaker or calorimeter) *Electric lamps of different wattages used to show relation between watts, amperes and volts Wattmeter* Determination of mechanical equivalent of heat electrically (low-resistance coil or low-voltage lamp may be used)
(2)	SAFETY TEACHING	
	Domestic wiring system Use of conduit Power circuits, earthing of electrical apparatus, etc	See Modern Science Memoirs, No 21.
(6)	CONSERVATION OF WORK. EFFICIENCY	
	Work as Force × Distance Measurement in ft -lbs Metric unit (erg and joule) Refer to lever and pulley systems Load × Distance load moves = Effort × Distance effort moves Work got out = Work put in (in absence of friction) Machines with friction Demonstrate by pulley system Work got out less than work put	Experiments with simple machines (pulley systems of various types)

YEAR V—PHYSICS (*continued*)

PERIODS	*CONTENT*	*COMMENTS*	*PRACTICAL WORK*
	in Efficiency Applications to various types of machines . bicycle, screw, gear trains, wheel and axle, etc		
(4)	POWER		
	Rate of doing work Power. Horse-Power. Derivation of unit of H P Determination of H P. (of boy) Brake Horse-Power and mention of indicated H P. Simple calculations.		*Determination of H P of a boy or electric motor*
(2)	STORAGE OF ENERGY KINETIC AND POTENTIAL ENERGY		
	Storage of work P E. Measurement in ft -lbs Storage of work in clock weights Storage in moving body Hammer head, projectile, etc K E Interchange of K E and P.E Conservation of Energy Galileo's pendulum. The isochronism of the pendulum Time of swing and length The balance wheel. Perpetual motion Loss	Time of swing and length, qualitative only	*Galileo's pendulum*

	of K E equals gain of P E in absence of friction When friction is present, heat is produced Energy chains	
(10)	MECHANICAL EQUIVALENT OF HEAT Caloric theory and discordance with the work of Rumford and Davy Everyday evidence Heat a form of energy Heat transformed into work Heat engine Operation cycles of steam, I C engines Quantitative aspect of transformation of work into heat Outline of Joule's work Demonstration of mechanical method for J Simple calculations of transformations of heat and energy Thermal efficiency of engines	*Experiments to show production of heat by work* Determination of mechanical equivalent of heat
Total 58		

[Time allocation for whole syllabus Biology 166 periods, Chemistry 155 periods, Physics 198 periods]

As has been mentioned in the foreword to this chapter, teachers of General Science often arrange their work, particularly in the early stages, around suitably chosen ' topics ', in order to exhibit the essential unity of Science The following is an example founded on actual experience of a three-year course in General Science arranged in this way, which includes much of the work we have recommended for the early years of our Basic Syllabus The work of each term is divided into three sections, A, B, and C, and these sections may be taken in any order. The unity of each term's work is emphasised and a thorough revision of each aspect of the work is made at the end of the term.

In addition to the work set out in the syllabus, continuous observations along the following lines are started at some convenient time ·

(*a*) Nature Diary—recording such things as the first appearance of flowers, migrants, frog spawn, butterflies (collection and identification of living things to be encouraged).

(*b*) rainfall, maximum and minimum temperatures, barometer readings, etc., are kept daily and recorded graphically.

The approach to the work is the study of things around us and the relation of these things to us as living beings , thus a study of the air suggests itself at once and is followed by a study of water, earth, etc. An ordnance survey map of the district is posted in the laboratory and is referred to as frequently as possible in connection with rambles, the town's water supply, the habitat of certain living things, etc.

FIRST YEAR

First Term. AIR.

Human beings suffocate if deprived of air. Buildings must be adequately ventilated. Flying. A fire burns best if it has a proper supply of air. What is air made of?

A *The air in relation to living things*

Study of breathing in the human being The difference between inspired and expired air Expired air contains gas which turns lime-water milky. Call this gas carbon dioxide. Since many living things breathe out carbon dioxide, can we detect it in the air? Show that it is present in small quantities.

Mechanism of breathing in the human being . mouth, nose, windpipe, lungs, ribs, diaphragm

Upkeep of vivaria and study of external features and habits of any interesting animal types, with, if possible, observations of their breathing

B. *What is air composed of?*

Living things and burning substances use air. Do they use all or part? Burn things in a limited supply of air, e g candle in a bottle (not candle over water). Choose strongly combustible substance, e g phosphorus (mention matches) and burn in a bell-jar over water. Air contains $\frac{1}{5}$ volume active gas—name Oxygen and $\frac{4}{5}$ volume inactive gas—name Nitrogen.

Living things suffocate in nitrogen. Living things use up oxygen from the air in breathing

Rusting of iron (*a*) uses up oxygen from the air, (*b*) needs both oxygen and water.

Water contains dissolved air—importance for aquatic life.

C *Ventilation, Wind.*

Methods of ventilating a room. A fire assists in ventilation. " Hot air rises " Experiments to demonstrate the movements of air when it is heated. Ventilation of mines, old and new (Use term convection) Experiments to demonstrate that cold air sinks. Convection currents Winds. Regular observations of rainfall, temperature and atmospheric pressure Charts of these. Experiments to illustrate the principle of the aneroid barometer.

Second Term. HEAT

Living things respond to warmth and protect themselves from cold. Many substances change when they are heated Substances expand on heating, e.g the liquid in a thermometer.

A *How living things adapt themselves for winter.*

Examples of hibernation. Hedgehog. Migrants Cold- and warm-blooded animals Body temperature. Trees in winter.

Spring : awakening to activity. Examination of leaf-buds. Experiments on germination of seeds : effects of warmth, light and moisture. Germinating seeds give off carbon dioxide and also produce heat. Development of the seed.

B. *Examination of common substances.*

Note carefully their appearance, touch, density, action of water, and especially the action of heat.

(*a*) Various metals, e g copper, lead, iron, zinc, magnesium.
(*b*) Various salts, e.g. common salt, washing soda, blue vitriol, nitre and potassium chlorate.

C. *Expansion, etc.*

Expansion of solids solids expand in all directions on heating and contract on cooling, but the amount of expansion and contraction is very small nevertheless the force of expansion and contraction may be very great Equal lengths of different solids, when heated equally, expand by different amounts. Bimetal strip

Applications of expansion of solids. Cases in which expansion is a disadvantage and how the difficulties are overcome

Expansion of liquids in a containing vessel Equal volumes of different liquids, when equally heated, expand by different amounts

Expansion of gases : amount of expansion is considerable. Thermometers based on expansion of solids, liquids, and gases and their respective merits

The transference of heat by conduction. Good and bad conductors and their uses.

Third Term. LIGHT AND OXYGEN.

The air contains oxygen and nitrogen ; we have isolated the nitrogen, can we isolate the oxygen ?

Study of a flowering plant and the effect of light on it.

Study of light and colour.

A. *Study of a green herbaceous plant, e.g. buttercup*

The flower and the functions of its parts. The leaf Production of oxygen by green leaves in sunlight only. Photosynthesis. Demonstrate starch production The stem and root.

B. Metals rusting in air take up oxygen from it. Can we make the rust give up its oxygen? Lavoisier's and Priestley's experiments on mercury "rust" (oxide) Preparation of oxygen from it. Preparation of oxygen from potassium chlorate and manganese dioxide or potassium permanganate Properties of pure oxygen Metals and non-metals burn in it, forming their oxides The oxides of non-metals dissolve in water to give acids—which turn litmus red The oxides of metals, if they dissolve in water, give alkalis.

Acids and alkalis neutralise each other to give salts

C. Green leaves kept in the dark lose their colour and the plant dies. Plants grow towards the light. Light is produced by hot bodies, e g. the sun, flame, electric lamp To produce light the body must be hot enough Light travels in straight lines. Light is reflected from a plane surface so that the angle of reflection is equal to the angle of incidence White light passed through a coloured glass acquires the colour of the glass. White light passed through a triangular prism emerges in rainbow colours—spectrum.

White light is composed of the spectrum colours.

Transparent and opaque colours explained.

SECOND YEAR

First Term. WATER

Water is important to all living things. Some living things exist entirely in water. The water supply of a town. What is water composed of?

A *Importance of water for living things.*

Aquaria. Their aeration by mechanical means and by green weeds. Study of a typical fish including external features, locomotion, respiration. Fresh water snails.

B *Tap water and its impurities.*

Pure water. Distillation. Solvent action of water. Action of substances on water copper sulphate (growing of crystals), zinc, copper, sodium, potassium and calcium.

Distinction between physical and chemical actions.

Preparation of hydrogen from steam by means of iron or magnesium. Use of hydrogen in airships Water contains hydrogen.

C. *The town's water supply.*

The reservoir. The water-tower. Reason for the water-tower. "Water finds its own level." Pressure depends on head of water. Manometers.

Rain, evaporation and condensation. Cloud, fog, dew.

Second Term. BUOYANCY AND FLIGHT

Hydrogen is used for balloons. What is the explanation of buoyancy? Study of living things which fly. Further study of hydrogen and water.

A. Study of a typical bird External features, habits, locomotion. Special adaptation to flight. Types of birds found in the neighbourhood. Other winged creatures

B. *Preparation and properties of hydrogen in detail*

The analysis of water by means of an electric current. Water consists of two parts by volume of hydrogen united to one part by volume of oxygen. The synthesis of water by burning hydrogen in air. Detecting the presence of water. Tests of purity. The volumetric synthesis of water.

C *Buoyancy and its relation to density.*

Simple methods of measuring the densities of solids and liquids. Flotation. Ships. Hydrometers Airships.

The hot-water system. Convection in water explained The motor-car radiator. Air has weight. Convection in air explained

Third Term WATER.

Further study of life in water. Water in the atmosphere. Further uses of hydrogen.

A. *The life-history of the frog*

Further study of pond life Observations of living creatures (visible to the naked eye) obtained on pond-dipping excursions. Marine aquaria.

B. The oxy-hydrogen, the oxy-acetylene flames and the gas flame Structure of flames Water and carbon dioxide are produced when coal gas is burnt.

Diffusion of hydrogen. The gas alarm. Explain by very elementary theory of molecules

The winning of metals, by reduction of oxides with hydrogen and with carbon

C. Water in the atmosphere, demonstrate by chemical and by physical means. Evaporation. Production of cold Butter-cooler. Refrigerators Freezing-point of water Wet- and dry-bulb thermometer. Humidity and health. Good and bad absorbers and radiators of heat. The thermos flask.

THIRD YEAR

First Term ENERGY

A. *Vital energy.*

The steam engine, chemical energy changed to heat energy changed to mechanical energy.

The animal. its differences from an internal combustion engine

Study of rabbit habits, external features, skeleton, food, dentition, alimentary canal. Throughout compare with human being.

Levers.

B. *Chemical energy*

Coal-mining. Origin of coal Coal-burning heat of combustion, products of combustion

Distillation of coal and wood Charcoal and coke, gas, tar and ammonia.

The gas works.

Petroleum, petrol, paraffin-wax, vaseline. Firedamp and natural gas.

The petrol engine.

C. *Electrical energy.*

The dynamo as source of electrical energy. mechanical energy to electrical energy.

The electric battery chemical to electrical energy.

The electric current and its effects: (*a*) physiological, (*b*) chemical, (*c*) magnetic, (*d*) heating

The electromagnet. Making magnets Properties of magnets. The electric bell.

Second Term. THE EARTH.

A. *The Earth and its place in the universe*

The solar system Seasons.

Suitability of the earth for life · temperature Atmosphere. Moisture

Soil. Its origin. Composition and kinds of soil Permeability and capillarity. Elementary surface tension Plants in relation to kinds of soil. Fertilisation of soil Animals of the soil, e.g. earthworm or mole.

B *The earth's crust*

Silicon, sand, silica, silicates.

Limestone: origin of chalk and limestone. Chemical analysis of shells and other forms of calcium carbonate.

The lime-kiln. Quicklime, slaked lime, lime-water.

Preparation and properties of carbon dioxide

Carbon monoxide Its poisonous nature.

C. *Astronomy.*

Shadows and eclipses.

Refraction in water, glass and the atmosphere

The convex lens. Camera. Magnifying-glass.

The concave lens.

Telescopes.

Third Term APPLICATIONS OF SCIENCE.

A *Discuss the work of the biologist in modern life.*

Insect pests: mosquito, house-fly, butterfly, wasp Their life-histories.

Useful insects. bee and silkworm.

Pollination of flowers

B *Discuss the work of the chemist in modern life.*

Practical study of some of the following

Soda-water, mineral waters, baking-powder, hard and soft water, soap

Fermentation by yeast

Mortar and cement.
Analysis of expired air and air dissolved in water.

C *Discuss the work of the physicist in modern life*
Ammeters and voltmeters.
Electrical motors
Lamps, heaters, fuse wires, etc.
Electroplating.

7 THE "EXTENDED" SYLLABUS

FOR those Schools who are able to devote more time to Science than that required for the basic syllabus, particularly towards the end of the course and for those pupils who will ultimately proceed to the Science Sixth Form, we make the following suggestions as to how the basic syllabus may be extended.

It is neither possible nor desirable to enter into great detail, since much of the additional time available will be devoted to a deeper treatment of certain topics already mentioned in the basic syllabus, but included there rather by way of illustrative material than for detailed study The list of topics we suggest is not set out in any particular order, but it is envisaged that they will be introduced by the teacher at convenient points in his consideration of the basic syllabus

PERIODS

PHYSICS

(2) *Conservation of Work and Efficiency* Idea of lever as machine with mechanical advantage and velocity ratio. Use of pulley in lifting weight and use of moving pulley to give multiplication of effort Link with M.A. and V R. of lever.

Vector Quantities. Composition and resolution of forces (and velocities). Applications to flight, sailing, etc. Triangle of forces.

(10) *Motion.* Some conception of average speed, uniform velocity, change of velocity leading to acceleration , distance-time, velocity-time, and acceleration-time graphs Equations of motion. Acceleration of falling bodies.

Momentum as distinct from energy. Newton's Laws. Units, absolute and gravitational

(8) *Surface Tension, Capillarity, Diffusion and Osmosis* Experiments to demonstrate the effect of surface tension. Experiments on capillary rise, drops and bubbles.

Simple demonstration of diffusion of gases of different density

Demonstration of diffusion of liquids and osmotic pressure. Surface tension, diffusion, osmosis, viscosity, change of state, gas pressure, considered from the standpoint of molecular theory. Discussion of part played by laws and hypotheses Brownian movement.

(2) *Thermometers.* Inclusion of temperature scale conversion by graph and calculation

(2) *Units of Heat* Inclusion of the use of thin calorimeters.

(2) *Change of State* Inclusion of cooling curves and a reference to vapour pressure.

(9) *Coefficients of Thermal Expansion.* Coefficient of linear expansion, meaning and determination. Straightforward calculations Coefficient of cubical expansion. Real and apparent expansion. Apparent volume coefficient of a liquid (by direct measurement or by weight thermometer) Relation between coefficients of expansion.

Expansion of gases. Charles's Law. Absolute temperature. Law of pressures. Combination of gas laws. Gas thermometer.

(2) *Reflection—Plane Mirror.* Inclusion of rotation of mirror and sextant.

(6) *Electrolysis.* Experiments with water voltameter to show that quantity of substance liberated depends on current and time of flow. The coulomb

Electrochemical equivalent, its meaning and determination. Simple treatment of the accumulator ; construction, charging arrangements, capacity, charging rate and recognition of charged and discharged accumulator.

(3) *Ohm's Law* Dependence of resistance on material, length, cross-section and temperature. Resistances in series and parallel.

Electrodynamics Fleming's Rule

(1) *Electromagnetic Induction.* Lenz's Law. Reversal in motor

(1) *Alternating Current* Induction motor

(21) ASTRONOMY

Note. As relatively few schools have facilities for the specialised teaching of astronomy and as instruments are not likely to be readily available in after life, chief emphasis is here laid on phenomena which may be observed with the unaided eye. The use of a planisphere should be encouraged and attention should be drawn to astronomical references in the daily press, especially to articles such as *Stars of the Month*, which appear periodically in *The Times* and other papers. All the topical information which the teacher requires is to be found in *Whitaker's Almanack* Perhaps the chief object of a short course of this kind is to arouse a feeling of wonder and to stimulate an interest which may provide lifelong pleasure.

Idea of the Ancients about Geocentric Universe

Copernicus' suggestions, simplification. The main features of the solar and stellar systems; sun, earth, planets, comets, meteors, stars, constellations, the galaxy and extra-galactic nebulae

The apparent diurnal motion of sun, moon and stars Circumpolar stars and their apparent motion. The Great Bear. Finding the Pole Star Diurnal motion explained by rotation of the Earth. Day and Night; time in relation to longitude (e.g. Greenwich, Land's End, Ireland, New York, Berlin, Australia).

Positions of moon on successive nights in relation to terrestrial objects and to stars; changes due to lunar motion. Length of lunar month. Phases of the moon and relation to rising and setting time. Connection between moon and tides with reference to times. Springs and Neaps Lunar and Solar eclipses; why they are rare.

Revolution of the earth. The Ecliptic Signs of the Zodiac (not to be memorised). Opposition and conjunction of planets Seasons in consequence of the revolution and tilt of the Earth's axis. Solstices and equinoxes, tropics, length of day in relation to latitude. Arctic and Antarctic circles The calendar and its developments Relative sizes and distances of sun, moon and earth Why sun and moon appear about equal in size Apparent annual solar motion. Weekly observations of planets and planetary motion. Asteroids. Observation of Mercury whenever possible Why it is difficult to see this planet Venus as morning and evening star. Appearance of sky at different latitudes Star catalogues, charts and their uses. Stellar distances Light year.

STRY

The Laws of Boyle, Charles, Gay-Lussac and Avogadro Relationship between relative density of a gas and its molecular weight. Gas volume relationships in the synthesis of steam, carbon or sulphur dioxide and hydrogen chloride.

Chemical equations and simple calculations based on them, including volumes of reacting gases.

Equivalents of acids and bases Simple volumetric analysis involving the use of normal solutions

Ozone and Hydrogen Peroxide Preparation and properties of ozone. Uses in air purification, etc. Preparation and properties of hydrogen peroxide Uses in bleaching and as an antiseptic

Nitrous Oxide. Preparation and properties Uses in anaesthesia

Hydrogen Sulphide. Preparation and properties. Poisonous nature. Precipitation of metallic sulphides under differing conditions—application to qualitative analysis.

The Alkali Industry. The manufacture of sodium carbonate by the Solvay process and of sodium hydroxide by an electrolytic process. Uses of these two substances and of the by-products obtained in their manufacture Sodium hypochlorite and sodium chlorate

(6) *General methods for the extraction of metals* Reduction of carbon and carbon monoxide. Mutual reduction of oxide and sulphide. Electrolytic processes Simple refining methods

(8) *Simple qualitative analysis* Identification of common basic radicals, such as lead, copper, iron, zinc, sodium, potassium, calcium, ammonium, and of acidic radicals, such as carbonate, chloride, sulphate, nitrate, sulphite, sulphide

(4) *Further treatment of oxidation and reduction* Change in valency during oxidation and reduction. Oxidising and reducing agents and methods for their detection.

BIOLOGY

(4) *Structure (morphology and histology) of the flowering plant* in relation to its primary functions respiration, photosynthesis, the transpiration stream, food storage, growth, irritability, movement and reproduction, and in relation to its environment. (Treated as a revision topic to gather together and extend knowledge gained in the basic course.)

(3) *Abnormal methods of plant and animal nutrition*—parasites and saprophytes, insectivorous plants, mycorrhiza and root nodules (included in basic course).

(2) *Tissues and cells* Cell division.

(5) *Further work on lower plants and animals* Amoeba, Spirogyra, Fern (arising from pond studies and leading to characteristics of living organisms and differences between plants and animals).

(2) *Further work on nervous system and sense organs.* Sensory and motor nerves and their endings. Spinal cord and brain Voluntary and reflex actions. Intelligence and instinct

(35) GEOLOGY

Note: The co-operation of Natural History Societies with work in this subject, much of which must of necessity be done in out-of-school hours, is most important. Interest may be maintained by offering prizes for geological work done voluntarily during holidays Geological maps of the districts which are visited may be drawn , sketches may be made of quarries and other sections which are seen , descriptions of the observed geology may be written ; and collections of rocks, minerals and fossils may be made The boy in a rural school can see rocks in quarries and can observe the outlines of the country and the courses of the streams , the boy in an urban school may observe many different rocks used as building stones and for roads in his town From the very start, boys should be encouraged to record observations bearing on the subjects discussed and to make drawings of the things they see Simple maps should be compiled and duplicated, so that each boy may have copies. Throughout this suggested course observation should be linked with practice, the connection between everyday life and science being kept in view. Most of the work is suitable for the first two years of a course in general science, if the teaching is kept on an elementary plane

The changing Earth. Surface alterations on Nature's surfaces and on artificial ones, e.g paths and country roads. Running water as an agent of erosion and transportation. Frost and its splitting action. Accumulation of waste (screes) at foot of walls, quarry faces and hillsides.

Hard and soft rocks (related to the above) Simple discussion of land forms showing differential weathering. Weathering of old walls. Dressed stones develop natural grain

Common rocks of neighbourhood (observed characters and differences). Rocks (stones) brought into district for buildings or roads, compared with local ones

The make-up of common rocks a conglomerate, a sandstone, a shale or clay, a limestone Examination of these rocks using lens and acid, both before and after breaking them up Comparison with loose pebbles, sand, mud and broken shells

The making of common sedimentary rocks : (*a*) raw materials in Nature and how they are obtained (see above) ; (*b*) hardening processes : pressure , cementing

Refer to artificial stones, e g. concrete, brick

The work of the sea · coast features ; sorting arrangement (stratification) ; intermingling of organic remains.

Earth movements raised beaches ; submerged forests , sea-shells in rocks above sea-level , tilting of beds ; dip.

Solvent action of water : solution and precipitation. (*a*) Solution of limestone in water and carbon dioxide. Scenery of a limestone country. Caves. (*b*) Precipitation of calcium carbonate in water-pipes, kettles and caves Preserving action of the deposit

Internal heat of earth (simple evidences) · rise of temperature in mines , hot springs ; lavas , crystals formed by cooling molten solid Crystalline rocks · Granite. Obsidian (cf. artificial glass).

Observation of rocks in the neighbourhood, in quarries or roads or buildings.

How to record observations on a map. Strike and dip. Outcrop. Width of outcrop related to thickness and dip. Drawing of simple sections.

The work of rivers . springs ; erosion and transport , valley formation , waterfalls ; meanders ; rejuvenation ; gravels , terraces ; deposition in sea , estuarine deposit , deltas.

Study of a map of a district dissected by river action. Dip and strike valleys. Escarpments Outliers. Section drawing through a scarp and an outlier

Glaciers : work of erosion and deposition ; evidences of glaciation in areas now free from ice.

Further study of igneous rocks . a volcano and its products. Ashes and breccias.

Lavas—(*a*) Fine types : glasses (*b*) Coarse types : including crystals and what they indicate. Non-extrusive types . dyke rocks ; Plutonic rocks.

Earth structures and movements : folding and faulting ; synclines and anticlines ; compression and tension ; jointing.

Map study and section drawing of synclines and anticlines. Their relation to forms of outcrop.

Common types of fossils. Living representatives of fossil forms.

Common minerals of the earth's crust and their recognition : quartz ; felspar ; mica ; hornblende ; calcite.

Mineral veins and ore deposits. Recognition of iron pyrites, copper pyrites, malachite, galena, haematite. Elementary ideas about mining. Extraction of iron from haematite and of lime from limestone.

Stratigraphy. Superposition. Broad divisions of geological formations. Primary, Secondary, Tertiary, Recent.

Cycles of denudation. Cycles of deposition. Unconformities and their significance.

Man's ancestry and prehistory : Palaeolithic man : his remains ; weapons and tools in cave deposits and gravels.

Neolithic man : his remains ; weapons and tools ; and burial mounds.

Bronze Age man : his structure ; flint and bronze weapons and tools ; his burial mounds and pottery.

Early Iron Age man : his structure ; weapons ; tools ; camps and pit-dwellings.

Economic Geology of to-day : peat ; coal ; oil.

8. SCIENCE FOR NON-SCIENCE SPECIALISTS

THE following suggestions are intended for those pupils who, while not specialising in Science in the Sixth Form, wish to continue their contact with it. It is assumed that such pupils will have covered the subject-matter of our Basic Syllabus during their pre-Sixth Form years and will be devoting not less than two periods per week for two years to Science in their Sixth Form course. These suggestions are based upon the Report of a Sub-Committee set up by the Science Masters' Association to consider the question of the teaching of Science to Non-Science Specialists, which was published in the *School Science Review*, No. 99 (February 1945), and we have adopted the aims of such a course as there defined, viz. " to inculcate a comprehension of the scientific method and of its specific contribution to the history of thought, to emphasise the connection of scientific discoveries and ideas with the historical background; to show the great importance of Science for the present and future well-being of our society, and lastly to relate Science to other subjects." Since the publication of the Report, some further experience in the teaching of this kind of work has been accumulated and is drawn upon in the modifications suggested. It is to be emphasised, however, that this field is still largely untouched and our syllabus is intended only as a general guide to those schools contemplating the institution of such courses. It is hoped that they will experiment boldly in making their own modifications and thus contribute to the general pool of experience.

1. GENERAL.

(*a*) *Scientific Method*

The following topics should be explicitly dealt with at convenient points during the course.

The appeal to experiment rather than to authority in scientific work.

The need for formulating a question clearly, for defining the terms used, for considering the alternative hypotheses or verifying the hypotheses in turn by planned observations or experiment.

The kinds of problem to which scientific method can be applied and those to which it cannot.

A 'Law' in science as a concise description of a group of related experimental or observational facts.

The function of hypothesis or theory in 'explaining' laws or the linking together of several laws by relating them to more fundamental or more commonly used concepts, the provisional nature of a theory and its use in predicting new facts or laws which may be verified or disproved by experiment.

(*b*) *The Beginnings of Science.*

The discoveries and theories of the philosophers of antiquity.

The position prior to the advent of the Greek Schools.

The Greek Schools—a brief account of the teaching of some of the well-known philosophers, e g. Thales, Pythagoras, Socrates, Democritus, Plato, Aristotle, Euclid, Archimedes—the philosophical approach to Science and the neglect of experiment by philosophers with Archimedes as the best known exception—Hippocrates and the beginnings of medical science

The Ascendancy and Decline of the Roman Empire and its effect upon Science—the Romans as essentially a practical people—the power acquired by the Church in consequence of the splitting of the Roman Empire

Arabian Culture—Alhazen

The Renaissance—beginning with the Arts and later spreading to Science—Roger Bacon, Leonardo da Vinci

The change to Inductive and Mathematical Science—Francis Bacon, Descartes.

The great development of Experimental Science in the sixteenth and seventeenth centuries Galileo—the Church and Science.

2 ASTRONOMY.

The Greek interpretation of the observations of naked-eye astronomy; the Ptolemaic System, the Copernican revolution, Copernicus, Tycho Brahé, Kepler, Galileo, Newton; the influence of astronomy on the development of mechanics (qualitative treatment)

The telescope in astronomy; the solar system, its chief members and relative dimensions; the tides

The determination of the distances of nearer stars by parallax and a brief outline of the methods used for more distant stars.

The spectroscope in astronomy, significance of bright and dark lines; the influence of temperatures, Doppler effect. Globular clusters, Cepheid variables, the galaxy. The extra-galactic nebulae.

3. PHYSICS

Mechanics.

The development of the mechanical view of the universe.

The work of Galileo and Newton.

The break with the mediaeval outlook.

Heat

The history of the thermometer and the measurement of temperature.

The measurement of heat—Black's work—the Caloric Theory

The Kinetic Theory of Heat—Joule's work as a model of careful experiment and his persistence against prejudice.

The principles of conservation and degradation of energy.

Light.

The corpuscular and wave theories.

Huyghens, Newton, Young and Maxwell.

The electromagnetic spectrum.

Interference, diffraction and polarisation

Modern ideas of light (the idea of wave-mechanics could be introduced here)

Electricity.

Early discoveries of the nineteenth century.

Faraday, his life and work.

Maxwell

Twentieth-century Physics

The enlargement of the scientific field to include the very small and the very large, involving the modification of the classical laws of the Newtonian era.

The discovery of X-rays.

The discovery of the electron. Thomson.

Early atomic models.

The Theory of Relativity—Matter and energy.

The Quantum Theory

Radioactivity—The Curies, Rutherford.

Transmutation, fission, nuclear energy

Short histories of the Royal Society, the British Association and other scientific societies.

4 CHEMISTRY.

An outline of the transition from alchemy to modern chemistry, with some appreciation of the work of such men as Boyle, Stahl, Black, Scheele, Priestley, Cavendish, Lavoisier and Dalton.

The atomic and molecular theories in the light of modern views of the structure of the atom. The correlation between electronic structure and chemical properties illustrated by reference to the periodic classification of the elements

Ways in which atoms can combine—transfer of electrons (electrovalency) and sharing of electrons (covalency)

Electrovalent compounds Ionic crystals. Simple ionic reactions, e g. neutralisation, precipitation, etc. Electrolysis

Covalent compounds Covalent crystals. The special case of the carbon compounds—ability of carbon atoms to form chains and rings Non-ionic reactions, e g substitution, addition, hydrolysis, condensation, etc. Simple treatment of organic chemistry, including elementary ideas on synthetic methods of preparation Structural formulae as indicating molecular structure. Molecular models and simple treatment of shapes of molecules.

Qualitative outline of the mechanism of chemical reactions. Influence of conditions on speed of reaction. Mass action. Energy relationships Catalysis. Chain reactions.

The colloidal state General properties of colloidal substances. Adsorption Foams, gels and emulsions.

The fundamental concepts outlined above should be illustrated by, and in many cases developed from, a study of several topics concerned with the applications of chemistry to everyday life or industry, such as metals and alloys , explosives ; drugs ; dyestuffs ; synthetic fibres , plastics , rubber ; photography ; the manufacture and importance of heavy chemicals , hormones ; insecticides ; fertilisers ; enzymes, etc.

The topics selected will vary with the interests of the teacher and pupils and the opportunities which the locality affords for first-hand acquaintance with the subject-matter.

5. TECHNOLOGY.

The development of tools.

The search for power—water-wheels—windmills, steam-engine, turbine and internal-combustion engine.

The use of electricity for the transmission of energy.

Sources of power and their utilisation.

Transport—use of the sledge, discovery of wheel from use of roller (comparison of rolling and sliding friction), the wheeled vehicle, the ship and the aeroplane.

Communication—use of visual signals and of sound. Electric telegraph, telephone, radio communication.

Social effects of technological changes. Reduction of drudgery and want. Distribution of population. Problems of leisure. Pollution of environment.

The relation between pure research and technological advance.

6. BIOLOGY.

History from the Scientific Renaissance to 1861.

Circulation of blood—Harvey.

Discovery of the microscope ; Hooke, Malpighi, Leeuwenhock.

Classification ; Linnaeus.

Comparative anatomy Cuvier

Protoplasm and the Cell Theory · Schlieden, Schwann, Schultze Characteristic properties of living matter with particular reference to man. Protoplasm ; cells and cell division.

Food A balanced diet . vitamins and dietetic deficiencies. The balance of nature . carbon and nitrogen cycles. Soil · use and misuse—erosion and exhaustion, reafforestation, irrigation and reclamation. Insect, rodent and fungal pests. Studies of world food problems.

Growth, illustrated by plant (apical growth and intercalary growth) and complete life cycle of a mammal. Hormones and growth.

Animal behaviour : central nervous system of man in simple outline, reflex actions, instinct and intelligence.

Diseases, their cause and methods of control Natural defences against disease The work of Pasteur, Lister and Koch : immunisation, antiseptics and antibiotics.

Variation and heredity Mendel's experiments with peas The Chromosome Theory Simple examples of inheritance in hybrids. Mutations. Determination of sex and inheritance of sex-linked characters.

Evolution. Evidence from studies in palaeontology. Geographical distribution, embryology and comparative anatomy. Theories of evolution. Darwin. Studies in population statistics. Eugenics.

9 SOME SPECIAL CONSIDERATIONS

1. THE UNIQUE POSITION OF MAN IN THE ANIMAL KINGDOM

THE experimental approach to human biology inevitably treats man as an animal and there is thus a danger that courses such as we have suggested may over-emphasise the similarity between man and the animals and that the neglect to draw attention to the unique position man occupies among them may leave our pupils with unbalanced views It is very difficult to lay down precise suggestions as to what can be taught on this theme particularly to pupils of 16, but we hope that some considerations such as the following may be present in the mind of the teacher, who will introduce such themes as and when he may feel his class to be ready to receive them :

> Though it may be that man's intelligence, his speech, his aesthetic sense, and even his ethical systems have derived from his animal progenitors, their existence is worthy of comment So too is the fact that man has a cultural as well as a biological inheritance : he ponders the past and anticipates the future · he is self-conscious and self-critical " at once actor, spectator and critic ". He strives for freedom in his individual life and in his social system, a freedom made possible by his intelligent control over his instinctive urges, a freedom which brings responsibilities which he often relates to his religious faith.

2. NATURAL HISTORY BACKGROUND.

In the syllabus no time is specifically assigned to purely Natural History topics It is felt that it is undesirable or even impracticable to provide for these in a formal syllabus Nevertheless, it is essential that the importance of this aspect of the work is not underestimated for it is fundamental to any real understanding of Biology, or of man's own environment Field work, the observation of living creatures in their natural habitats, must form the basis of this work and a proportion of the studies must be of this type Other topics may then be dealt with by producing replicas of some aspects of the habitat in the laboratory or school garden, by bringing portions into the laboratory, or by bringing in selected plants and animals, preferably for examination whilst still alive in order that their structure may be studied in relation to their life processes Then, and only then, is it permissible to fill in gaps by means of preserved specimens or photographs

Mention has been made in the notes on the Biology Syllabus of a number of instances where field studies may be undertaken, but the actual times and examples must always be determined by local and seasonal considerations In particular it should be remembered throughout that a portion of the work in the fifth year is the study of one particular habitat The intention is that this period should be used for summarising and formalising a large number of observations which have been made during the preceding four years and the need for this preparatory work must be kept in mind at all seasons throughout these four years.

3 Astronomy and Geology.

In regard to the Basic Syllabus, we adhere to the opinion expressed by our predecessors in the following extract from the *Teaching of General Science*, Part I, p. 34 :

> Despite their obvious claims to inclusion, we decided to omit specific mention of Geology and Astronomy from the Syllabus we now present, the shortness of the available time being one of the chief reasons We are also influenced by the thought that in most schools it is difficult to make arrangements for observational work Further, in many schools, Geology is taught by the Geographers in a way which suffices for the purpose we have in mind and though a little overlapping in the teaching is desirable, too much may be wasteful of time Moreover, although a master who, teaching General Science as we think it ought to be taught, can hardly fail to mention facts of astronomical and geological import while he is dealing with certain parts of our Syllabus, these subjects, so far as they can be carried in very elementary treatment, seem to use no fundamental principle which is not dealt with elsewhere in our syllabus

We have, however, included suggestions for work in both these branches in our " Extended " Syllabus (Chapter 7), but we would emphasise the vital necessity for observational work for astronomy and field studies for geology , otherwise the course will degenerate into the mere handing out of information perhaps illustrated by pictures and slides Such information may be interesting and important to the pupil, but unless based on observation and experiment it cannot be called Science, and the Science lesson is not the place for imparting it.

4 TREATMENT OF ATOMIC THEORY.

In courses of Chemistry as a separate subject to the first school examination, it has been customary to attempt a logical treatment of the Atomic Theory The gravimetric laws led to the Dalton Atom. The law of gaseous volumes led to the molecule and to Avogadro's Hypothesis Some evidence was produced for the diatomicity of the hydrogen molecule. The constancy of the gram-molecular volume at S.T P. was established and molecular weights calculated from vapour density measurements The atomic weights of a few non-metals were derived from a flimsy argument based on Cannizzaro's method and of a few metals from a still more flimsy argument, based on Dulong and Petit's Law.

Experience of attempting to teach on these lines has led to the view that it produces more satisfaction in the mind of the teacher than comprehension in the mind of the immature pupil. Whether or not such a treatment is desirable for the able pupil at this stage, it is not suitable, we feel, for the General Science course.

In the early stages, possibly in the first year, certainly in the second year, chemical symbols should be introduced as a kind of shorthand to stand for elements (without any definition of atoms) and simple formulae for compounds, e.g. PbO, CO_2, NaOH. Towards the end of the second year the ideas of atoms of elements, molecules of compounds and later, molecules of elements should be given, not as facts, but as supplying a mental picture by which we try to account for the facts we observe Equations are balanced groupings of these formulae. Throughout the third year, suitable opportunities are numerous for giving practice in the building of equations. Direct attempts to teach valency at this stage are probably unwise ; it is better to let the idea emerge gradually and to draw specific attention to it when this is judged to have occurred. By the fourth year, considerable facility should have been acquired in the use of equations, and the pupils should be ready to receive the idea that electrolytes differ from non-electrolytes in that their atoms or radicals are electrically charged (ions), the feeble conductivity of water being accounted for by supposing that it is feebly ionised :

$$H_2O = H^+ + OH^-$$

With a good class some teachers may wish to proceed to an explanation of the reactions at the electrodes The conception of the Activity Series of the metals (and hydrogen) has by this time been given and the reactions at the cathode can be explained · the element with the lowest energy being the most easily discharged. It is reasonable to extend the activity idea to the anions and so to explain the phenomena at the anode The theory of ions can then be shown to give a more satisfactory explanation of the ordinary chemical reactions of electrolytes, stressing particularly the hydrions in acids and the hydroxyl ions in alkalis.

The quantitative work on equivalence in the fifth year then makes possible a development of the Atomic Theory to include a consideration of the relative weights of the atoms and molecules and the use of these for simple calculations of reacting weights

5 UNITS IN PHYSICS

In any Physics course the evolution of a system of units causes much difficulty to beginners There is no reason why, even in a General Science course, the method of building an absolute system of units depending on the fundamental units of mass, length and time, should not be outlined. Obviously, all the absolute units involved in the whole syllabus cannot be defined Therefore, at some point, a unit must be *named* without being *defined*. This arises because Newton's Laws of Motion are not included in the syllabus and hence, the absolute unit of force, the dyne, cannot be derived.

All the Mechanics for General Science can be covered without using absolute units. The British system of units is adopted and these are real to the beginner and comparatively easy to understand. Trouble arises, however, with the electrical units, for these are founded on the fundamental units. In the General Science course, then, there are two methods of approach to units. For those who do not intend to study science beyond the School Certificate stage, it is suggested that only the British System of Units be employed in the mechanics for the measurement of force and work. When the electrical units are encountered, these should be *named* only. If desired, the international units of current, potential difference, and resistance can be given. The watt has to be defined in terms of the ampere and volt, which is not strictly correct.

The alternative approach which may be preferred for the future science specialist, is to *name* the absolute unit of force (dyne) or work (erg) in the early stages of the mechanics. As pointed out above these units cannot be *defined* without Newton's Second Law. The practical unit of work (joule) and the unit of work (watt) can then be *defined*. This next leads to the volt and the derivation of the expression for the energy consumed in a conductor expressed in joules and calories. The definition of the ampere must be left for post-school certificate Physics, for this depends on quantitative magnetism outside the Syllabus.

6 PROBLEMS ON CHANGING TO GENERAL SCIENCE

It is inevitable that the introduction of General Science courses into a school where formerly one or more only of the separate branches were taught presents a number of problems, but, when the advantages of the broader based course in Science are appreciated, solutions to these problems can be found. Not the least of them concerns staffing.

Beyond question, the most desirable arrangement, at any rate in the early stages, is for all the Science for a given class to be in the hands of one teacher What has been called the essential unity of Science lies in its method and we do a great service to the community if we give to its future citizens some idea of what the method is and some realisation of its wide applicability A pupil who begins his scientific studies under more than one teacher, teaching only their own specialist branches, is likely to feel that there are different sciences more or less narrowly confined and he is less likely ever to be able to apply his training outside those fields. We recommend for at least the first two years of a four-year course, or at least the first three years of a five-year course, that unity should be maintained in the teaching

The reluctance of teachers trained in the Physical Sciences to undertake the biological work and of biologists to undertake work involving Physics and Chemistry, is recognised. But we take the view that there is nothing in the Basic Syllabus beyond the powers of anyone with a scientific training both to appreciate and to teach Perhaps an instance of how this difficulty has been met in one school may be useful The school was a three-stream school and had three specialist teachers. Jointly they drew up a teaching syllabus to cover the first three years, each putting forward material which he thought to be important, the others requiring him to justify his material from the point of view of the kind of knowledge and training which the ordinary, educated citizen ought to possess. In doing this each became convinced of the importance of the other branch of Science and each was forced to examine critically his reasons for teaching the various parts of his own. Each was then given one of three parallel first-year Forms and at first weekly, and later at less frequent intervals, meetings were held to discuss progress and to plan the work for the immediate future Needless to say, each was reading into the branch with which he was least familiar and his studies were being guided by his specialist colleagues This method proved successful and while it may not meet the difficulties in other schools, it may suggest lines along which solutions are possible

For the last year or two of the General Science course and when the allocation of time for Science is usually more liberal, there is much to be said for some subdivision of the work The development of Science is towards classification, towards the isolation of types of problem, that is, towards specialisation. (Notice that this is a development and not a starting-point.) It is desirable that before the conclusion of the general school course, the pupil should be made aware of this

A second problem concerns laboratory accommodation No doubt the ideal solution is for the elementary work to be taken in a general purpose laboratory and later, when the increasing complexity calls for subdivision, for it to pass to the specialist laboratories Building problems, however, are much less flexible than human ones and for most schools this ideal is unattainable.

For a three-stream school, with three laboratories, one solution is for three parallel forms to take Science lessons during the same periods, so that at reasonable intervals, say every third of a term, rooms may be exchanged and the work so planned that each part can be carried out in the most suitable laboratory While a solution on these lines may be possible in some schools, it is freely admitted that in the overcrowded state of many Grammar Schools no really satisfactory solution may be possible at present and it may be necessary to conduct the whole of a year's work in General Science in one of the specialist laboratories When this occurs it may be desirable to assemble the equipment needed for a week or more, on trays in cupboards set aside for the purpose, in the room where it is to be used This involves a certain amount of planning in advance, but it is reasonably satisfactory for elementary work. Conditions of this kind, however, provide a further reason for subdividing the later stages of the work into the three main branches, to be taught in the specialist laboratories.

10. EXAMINATIONS

IN the construction of the syllabus we have tried to include what is both teachable and worthwhile, irrespective of its suitability or otherwise for examinations While it is true that many of the qualities of mind which we believe our pupils may acquire from the liberal courses we have planned are beyond the scope of examinations to assess, we realise the necessity for and the powerful influence exerted by examinations. In the previous Report, very specific and, we think, very wise recommendations were made for examining in General Science. By now, however, most examining boards have adopted techniques very much in the spirit of that Report and we feel that there is no longer any need to enter into such detail. For the new General Certificate of Education we anticipate that the examination in General Science will play an increasingly important part at the " ordinary " level.

We emphasise that the best kind of teaching is always little influenced by the examination and we deprecate in the examination anything which would limit the freedom of the teacher to experiment or to follow, from time to time, what may appear to be profitable digressions from the syllabus. There is much more in the business of educating than the imparting of knowledge in a form readily reproducible in examinations It is one of the dangers of any system of examinations that we may come to value only what we can test, and this peril should be ever present in the minds of both teacher and examiner.

Our predecessors laid great stress on the desirability of supplementing the written examination with further use of teachers' estimates in order to give due weight to those ' by-products ' of our teaching, those " many important qualities which cannot be valued adequately " by written tests While we are very much in sympathy with this point of view, we realise the difficulty of standardising such estimates. We have felt bound, therefore, to content ourselves at present with the above insistence on the limitations of written examinations, though we should welcome more research into the wider use of such estimates.

It is, of course, recognised that external examinations can exert a beneficial influence upon schools by demanding that the teaching shall not deviate too far from certain desirable paths, and in this connection we quote from the previous report:

> The written tests should be compiled to attain the following objectives
>
> (1) all the children should know thoroughly a limited range of facts and principles of fundamental importance,
>
> (2) all the courses taken in schools should cover parts of the three main sciences at least (and preferably parts of others as well);
>
> (3) this wide field should be combined with limited specialization in certain directions, i e. teachers of science should be able to direct their attention towards topics specially relevant to the environment of their school or to their own special interests and abilities (local specialization)

One of the problems with which examiners of General Science have been faced, and one of the causes of dissatisfaction among teachers, who have prepared pupils for some of these examinations, has been that the breadth of the syllabus to be tested has made adequate sampling of its parts difficult in one examination. We are of the opinion that it is not desirable to attempt to assess the results of some five years' work over so broad a field as even our basic syllabus in a single paper. At least two papers at the "ordinary" level should be set One paper should consist of a wide range of the now familiar "New-Type" short answer questions designed to secure objectives (1) and (2) above. Another paper should consist of questions requiring essay-type answers designed to estimate certain aspects of scientific knowledge to which we attribute importance, such as the ability to marshal the points of an argument in orderly sequence or to write down clear instructions for the performance of an experiment. It should be remembered that an important part of the training we try to give to our pupils lies in the ability to express themselves with clarity in English and in this type of question candidates who have not acquired this skill are automatically penalised. It is probably inadvisable for questions of these two types, designed to test different qualities, to be incorporated in the same paper, since candidates are then tempted to answer the essay-type questions with the brevity which is encouraged in the short-answer questions In examinations concerned with the Extended Syllabus no different principles are involved and further questions of both types are desirable.

We now give with slight modifications a list, taken from the previous Report, of the specific features with which we consider the teaching and examining of General Science to be concerned In each case is added a question connected with that specific factor

I. *Acquisition of Scientific Information and Knowledge.*

(i) Knowledge of empirical facts
e.g. Name two gases which are denser than air.

(ii) Power of reproducing verbally laws or principles
e g State Boyle's Law.

(iii) Knowledge of technical terms, or of words used in science
e g Explain the meaning of "latent heat".

(iv) Ability to identify forms, structures, processes and to state their functions
e g A labelled diagram of a flower is given. The candidates are asked to name the parts and to state their function

(v) Power of explaining verbally the meaning of a law or a principle
e g What is meant by Conservation of Energy? Show how this conflicts with the idea of Perpetual Motion

II *Development of Scientific Modes of Thought.*

(i) Ability to use scientific knowledge to explain facts of ordinary life—unification of experiences, i.e from facts to principles.
e.g. Explain (*a*) the occurrence of the blue flame that often appears over a coal fire and (*b*) why soap forms a curdy precipitate with hard water.

(ii) Enlargement of experience by recognising in ordinary life instances of the operation of natural laws, i e. from principles to facts.
e g Describe three experiments or observations which

show that thermal radiation obeys the same laws as light

(iii) Capacity to distinguish between facts and hypotheses.
e.g. Read the following passage. Then write down (*a*) which of the statements are facts, (*b*) which are verifiable generalisations and (*c*) which are mere statements of opinion

(iv) Isolation of relevant facts from a complex situation
e.g. A fairly complicated experiment is described and the candidates are asked to point out which of the facts mentioned would be relevant to the solution of the problem considered.

(v) Ability to plan experiments and to test statements.
e g. (*a*) How can one find out that a certain muscle in a frog's leg is an extensor and not a flexor ? (*b*) Devise experiments to test the following statement · "Saccharine is 500 times sweeter than sugar."

(vi) Ability to apply generalisations to new problems.
e.g Two identical cubes of wood are sterilised and placed in separate moist chambers. Block A is kept sterile. Block B is inoculated with a fungus, which grows and thrives in the wood. How will the dry weight of these blocks probably compare at the end of three months ? Why ?

(vii) Ability to draw reasonable generalisations from experimental data.
e g Nine hundred seeds of a certain plant were divided into nine groups of 100 seeds each. Each group of 100 seeds was placed in a germinator, they were all kept in the dark under the same conditions. But each germinator was kept at a different temperature. The following data were obtained

Temperature, ° C	6	8	11	13	18	25	30	35	39
Number of seeds which germinated	0	0	0	0	16	50	84	30	0

What generalisations could you draw from this experiment ?

(viii) Ability to recognise problems which lend themselves to scientific treatment, and the contrary.

e g. Which of the following statements could be investigated experimentally and in what way?

(*a*) Rain before seven, fine before eleven

(*b*) A hot-water bottle airs a bed

(*c*) Virtue is its own reward

III. *Application of Scientific Knowledge to Socially Desirable Ends*

Ability to recognise situations or unsolved problems in which scientific knowledge could usefully be employed

e g (*a*) A woman planted some flower-seeds beside her house The plants did not grow very well. The woman next door planted seeds of the same kind of flower. These plants grew very well. (*b*) A farmer had a flock of chickens. He noticed that on some days he would get many eggs and on other days he would get very few eggs. What kind of information would you need before you could explain these differences?

IV. *Practical Powers or Skills*

Scientific knowledge involves power to use and to handle as well as power to "talk about things" Such skills cannot well be tested by written examinations. The candidates would have to be placed in specific situations calling for use of specific skills The following factors can easily be distinguished

(i) Development of manual skill and dexterity

(ii) Ability to handle scientific material and apparatus (i e. skill in laboratory technique)

(iii) Development of ideals of careful, neat and accurate work.

(iv) Ability to apply scientific knowledge to solve the practical problems of everyday life.

(v) Ability to devise experiments and to carry them through.

The material of Section IV cannot easily be tested by written examinations, but here school records might give valuable information.

When we come to consider papers at the " ordinary " level for more mature candidates who are probably doing advanced work in subjects other than science, it is clear that different considerations are involved. As each school may emphasise different aspects of the syllabus, the knowledge of candidates will vary widely In any case, the testing of mere factual knowledge is relatively unimportant in this context What the examiners will be required to elicit is evidence that the candidate has acquired some appreciation of the contribution of science to general culture, some knowledge of its methods and of its impact on society. This will mean that objective tests will probably be inappropriate and that experiments will doubtless be made with papers consisting of a liberal choice of questions of the essay type.

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